Morphological, Cytological and Biochemical characterization of *Vigna unguiculata* and related taxa for identification of donor sources

Thesis submitted to the

Bundelkhand University, Jhansi

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In

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By

Geetanjali Sahay

Under the supervision of
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ICAR

IGFRI

Dedicated To
My Parents

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To
The Vice Chancellor
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Date: 12th September, 2008

Sub: Submission of Ph. D. Thesis.

Sir,

I am forwarding herewith the thesis entitled "Morphological, Cytological and Biochemical Characterization of *Vigna unguiculata* and related taxa for identification of donor sources" by Mrs. Geetanjali Sahay for the award of Doctor of Philosophy in Botany, Bundelkhand University, Jhansi. The work has been carried out at Indian Grassland and Fodder Research Institute, Jhansi under the supervision of Dr. D. R. Malaviya, Principle Scientist.

Thanking you,

Yours faithfully,

kasingh
12/9/2008

(K. A. Singh)

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CERTIFCATE

It is to certify that the thesis entitled "Morphological, Cytological and Biochemical Characterization of *Vigna unguiculata* and related taxa for identification of donor sources" is an original piece of work done by Mrs. Geetanjali Sahay, under my supervision and guidance for the award of degree of Doctor of Philosophy in Botany, Bundelkhand University, Jhansi, India.

I further certify that –

- It embodies the original work of candidate herself.
- It is up to the required standard both in respect of its contents and literary presentation for being referred to examiners.
- The candidate has worked under me for the required period at Indian Grassland and Fodder Research Institute, Jhansi.
- The candidate has put in the required attendance in the department during the period.

10/9/08.

(D. R. Malaviya)
Supervisor

DECLARATION

I hereby declare that the thesis entitled "Morphological, Cytological and Biochemical Characterization of *Vigna unguiculata* and related taxa for identification of donor sources" being submitted for the award of degree of Doctor of Philosophy in Botany, Bundelkhand University, Jhansi, is an original piece of research work done by me under the supervision of Dr. D. R. Malaviya, Principle Scientist, IGFRI, Jhansi and to the best of my knowledge, any part of this thesis has not been submitted for a degree or any other qualification of any University or examining body in India or elsewhere.

Gitanjali Sahai

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Gitanjali Sahai

Jhansi
09th September, 2008

(Geetanjali Sahay)

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LIST OF NOTATIONS

AD	Anno Domini (In the year of our Lord in Latin)
Anon.	anonymous
BC	Before Christ
cv. gr.	cultivar group
DAS	days after sowing
Eq.	equation
Eqs.	equations
i.e.	that is
FAO	Food and Agricultural Organization of United Nations
Fig.	figure
Figs.	figures
g	gram
ha	hectare
ICAR	Indian Council of Agricultural Research
IGFRI	Indian Grassland and Fodder Research Institute
IITA	International Institute of Tropical Agriculture
kg	kilo gram
No.	number
MT	metric tonnes
ppm	parts per million
rev/min	revolution per minute
Sl.	serial
ssp.	sub species
USA	United States of America
USDA	United States Department of Agriculture
var.	variant
viz.	namely
°C	degree centigrade

CHAPTER 1

INTRODUCTION

Cowpea, *Vigna unguiculata* L. (Walp), is one of the most ancient crops (Summerfield *et al.*, 1974). The history of cowpea dates back to ancient West African cereal farming, some 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet (Quinn and Myers, 2002). Cowpea has a number of common names such as crowder pea, black-eyed pea and southern pea. It is internationally also known as lubia, niebe, coupe, frijole, seub, niao, wake and luba hilu. However, they are all the species *Vigna unguiculata* L. (Walp), which in older references may be identified as *Vigna sinensis* L. Cowpea is a crop well adapted to many areas of the humid tropics and temperate zones. It tolerates heat and dry conditions, but is intolerant to frost. Germination is rapid at temperatures above 18.3° C whereas, colder temperatures slow the germination. The crop performs well on wide variety of soils and soil conditions, but performs best on well-drained sandy loams or sandy soils where soil pH is in the range of 5.5 to 6.5. As a legume, cowpea fixes its own nitrogen, and does not need nitrogen fertilizer. Some of the vigorous, vining, varieties of cowpeas are excellent nitrogen producers as a cover crop. The estimated annual nitrogen fixation is 73-354 kg/ha with a global average of 198 kg/ha, which is double that of soybean (FAO, 2006).

The majority of cowpea is grown in West and Central African countries. The largest production of cowpea is in Africa, with Nigeria and Niger predominating. Brazil, Haiti, India, Myanmar, Sri Lanka, Australia, the U.S., Bosnia and Herzegovina also have significant production of cowpea. Its origin and subsequent domestication is associated with pearl millet and sorghum in Africa. Cowpea is now broadly adapted and cultivated around the world for seed, vegetable (leafy greens, green pods, fresh shelled green peas, and shelled dried peas), cover crop and fodder crop. It is also used as a green manure crop, a nitrogen-fixing crop and a crop for erosion control. It has hay yields of about 5 tonnes/ha (FAO, 2006). It is harvested as dried seed, black-eyed pea and pink-eyed or purple hull southern pea for marketing. Some cowpeas are harvested fresh while the seeds are having high moisture content. It is often cooked with water and stored in cans or kept frozen for consumption. Various soups and bean mixes

incorporate these products as well. There is also some consumption of the whole pea pod as a fresh vegetable.

The value of cowpea lies in its high protein content, its ability to tolerate drought, and the fact that it fixes atmospheric nitrogen which allows it to grow on, and improve poor soils. Cowpea is considered nutritious with protein content of seed of about 23 per cent, fat content of 1.3 per cent, fibre content of 1.8 per cent, carbohydrate content of 67 per cent and water content of 8 to 9 per cent. As in most legumes, the amino acid profile complements cereal grains. Compared to cereal grains, the protein in cowpea seed is rich in the amino acids, lysine and tryptophan. Methionine in cowpea grain is 1.9 per cent more than other legumes (Yadav and Vyas, 1994). Therefore, cowpea seed is valued as a nutritional supplement to cereals. In many areas of the world, cowpea is the only available high quality legume hay for livestock feed (Phillips *et al.*, 2003). Green fodder of cowpea contains 13.21 per cent crude protein, 40.8 per cent crude fibre on dry matter basis and its in vitro dry matter digestibility is 42.72 per cent (Shah *et al.*, 1988).

About 7.56 million tons of cowpea seeds are produced worldwide annually on about 12.76 million hectares (FAO, 2006). Sub-Saharan Africa accounts for about 70 per cent of total world production. In India, cowpea is still a minor crop and is grown only in some parts of Rajasthan, Gujarat, Maharastra, Karnataka and Tamil Nadu. It has great potential for sustainable agriculture in marginal lands and semi arid regions of the country. Though, accurate data on cowpea area and production are not available, it is estimated that about 6.5 lakh ha is under different forms of cowpea out of which 3 lakh ha are under fodder cowpea (Singh *et al.*, 1997). The highest yield of cowpea genotypes in India have been found in the range of 775 to 1006 kg/ha seed (Anon., AICRP, 1997). The average yield of cowpea grain is as low as 300 kg/ha. The productivity of green fodder cowpea is in the range of 25-45 t/ha. The largest area under this crop is in Rajasthan where it is cultivated in 1.20 lakh ha with a production of 43.2 thousand tones of grain (Henry *et. al.*, 2003).

Cowpea is a warm-season, annual, herbaceous legume. Plant types are often categorized as erect, semi-erect, prostrate (trailing), or climbing. It possesses wide intra species diversity for various traits. Growth habit ranges from indeterminate to fairly determinate with the non-vining types tending to be more determinate. Cowpea is day neutral, and primarily self-pollinating. Cowpea pods are smooth, 6 to 10 inches long, cylindrical and somewhat curved. Pod colour at green-mature stage is commonly green but may be yellow or purple for use as a vegetable. As the seeds dry, pod colour becomes

tan or brown. Many cowpea cultivars have a vining growth habit, but modern plant breeding has led to more upright, bush-type cultivars. The vining type is preferred for forage or cover crop use, while the bush type is better suited for inter-cropping.

Diseases such as root rot, leaf spot, anthracnose, rust, and bean common mosaic and abiotic stresses such as drought and low soil fertility are important constraints to cowpea production wherever the crop is grown. Cowpea Yellow mosaic virus causes 10 to 100 per cent loss in fodder seed production. Pests of cowpea include aphids, leaf folder, hairy caterpillar, semilooper and storage weevil, which cause reduction in crop yield.

Cowpea is known to have tolerance to soil moisture deficit through in-built avoidance phenomenon due to characteristic long maturity, slow growth and poor yield potential. It customarily suffers to the terminal drought due to forced maturity, leaving almost no difference for maturity at the varietal level. This crop also suffers from drought-induced heat and certain specific insect pests and diseases from drought. Drought is a common cause of yield loss, with two types of drought distinguished *viz*. 1) terminal drought; and 2) intermittent drought. The only traits that have proven to result in greater harvest index in both terminal and intermittent drought are earliness and partitioning towards reproductive structures.

With the use of suitable genotypes/varieties and proper inputs, the production of cowpea can be enhanced considerably. At present varieties grown in the country are mostly indeterminate or semi determinate types. There is a need for developing varieties with early maturity, determinate growth habit and high yield. In plant-breeding programme, it is necessary to screen and identify phenotypically stable genotypes of cowpea, which could perform uniform under different environment conditions. Such genotypes are useful for commercial production. The relative basic information on cowpea is not quite sufficient. Therefore, present investigation is proposed to collect this information for cowpea, which may be useful to initiate an effective breeding programme.

Proper characterization helps in unambiguous discrimination between accessions. The classical methods of characterization are based almost exclusively on agro morphological and physiological traits. These are often quantitative in nature and influenced by environment, hence, are not very distinctive and dependable. Thus, there is need of employing more sensitive and robust characterization methods. One such method is use of biochemical and cytological characterization, which addresses the limitations

associated with morphological markers. Therefore, this study has been taken with the following objectives.

1. Evaluation of germplasm lines for forage and grain yield and yield attributes, character correlation and path analysis for determining the contribution of various traits to forage and grain yield.

2. Establishing distinctness of lines based on some morphological, physiological and biochemical traits for further utilization in breeding programme.

CHAPTER 2

REVIEW OF LITERATURE

This chapter deals with the brief review of the research work conducted in the area of morphology, cytology and biochemistry with a focus to use the available knowledge for cowpea crop. The review is presented under the following heads.

a) Nomenclature, taxonomy and classification
b) Geographical origin, domestication and distribution
c) Relations between cultivated and wild cowpea
d) Production statistics
   Worldwide cowpea production
   Cowpea production in India
e) International status of cowpea improvement including
   Plant genetic resources
   Conventional method of cowpea improvement
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   Cytology
f) National status of cowpea improvement including
   Plant genetic resources
   Conventional method of cowpea improvement
   Biochemical studies
   Isozyme application in cowpea
   Cytology

2.1 Nomenclature

Cowpea, *Vigna unguiculata* L. (Walp), is also commonly referred to as Southern pea, Black-eye pea, Black-eye beans, Crowder pea, Lubia, Niebe, Coupe or Frijole. In Francophone countries of Africa the name nie´be´ is used often. Local names for cowpea

are seub and niao in Senegal, wake in Nigeria, and luba hilu in Sudan. Common name of the cultigroups of cowpea are as following.

1. *Vigna unguiculata* cv.gr. *cylindrical* L. Verdc. Common names: *Catjang*, Hindu Cowpea; Synonym: *V. cylindrical* L.
2. *Vigna unguiculata cv.gr. sesquipedalis* L. Verdc. Common names: Yard long bean, Asparagus bean, Pea bean; Synonym: *Dolichos sesquipedalis* L. *Vigna sesquipedalis* L. *Vigna sesquipedalis* L. *Fru.* with *Vigna sinensis ssp. sesquipedalis* L. Van Eseltine., *Vigna sinensis* var. *sesquipedalis* L. Aschers and Schweinf.
3. *Vigna unguiculata* L. (Walp) cv.gr.. *unguiculata.* Common names crowder pea, Black-eyed pea, Southern pea; Synonym: *Vigna sinensis,* L. Savi ex Hassk.

The extreme variability of the cowpea species has led to a number of commercial cultivars grouped by the variance in seed shape, size and colour. These are described as following.

1) Black-eyed or pink-eyed/purple hull peas — the seeds are white with a black eye round the hilum. The 'eye' can be of other colours like pink, purple or shades of red. The eye colour darkens to a dark purple on drying. The pods are purple-like on the pink-eyed/purple hull type. The seeds are not tightly packed or crowded in the pod and are of kidney or oblong in shape.

2) Brown-eyed peas — pods range in colour from green to lavender and also along the length. The immature seeds, when cooked, are medium to dark brown, very tender and have a delicate flavour.

3) Crowder peas — seeds are black, speckled, and brown or brown-eyed. The seeds are "crowded" in the pod and also tend to be globular in shape.

4) Cream — seeds are cream coloured and not crowded in the pods. This is an intermediate between black-eyed and Crowder types.

5) White acre type — seeds are kidney shaped with a blunt end, semi-crowded and generally tan in colour. Pods are stiff with small seeds.

6) Clay types — these older varieties are medium to dark brown in colour and kidney shaped but is rarely grown.

7) Forage cultivars — adapted for use as fodder, or cover crop use.

2.2 Taxonomy and classification

Verdcourt (1970) and Marechal *et. al.* (1978) classified cowpea as following.

Order	: Fabales
Family	: Fabaceae
Subfamily	: Faboideae
Tribe	: Phaseoleae
Subtribe	: Phaseolinae
Genus	: *Vigna*
Species	: *unguiculata*

Most of the taxonomists agree that cowpeas belong to family fabaceae, and the botanical species *Vigna unguiculata* L. (Walp). However, classification and nomenclature of taxa at the intra-specific level are still debated. Verdcourt (1970) sub divided cowpea into three subspecies *viz. unguiculata, catjang* and s*esquipedalis*. Other researchers (Westphall, 1974; Marechal *et. al.*, 1978; Ng and Marechal, 1985) grouped all the cultivated cowpea under *V. unguiculata* that was subdivided into four semi-groups or cultigroups *viz. unguiculata, biflora, sesquipedalis,* and *textilis*. Most of the cowpea breeders have adopted Marechal *et al.* (1978) cultigroup scheme for classification of cultivated *V. unguiculata* taxa. *Unguiculata* is the major group having general cowpea morphology and is grown all over cowpea growing areas. *Biflora* or *catjang* is characterized mainly by its small erect pod. *Biflora* is grown mainly in South East Asia. *Sesquipedalis*, also known as yard long bean is differentiated mainly by its very long pods and climbing habit. *Sesquipedalis* is grown for its fresh pods, mainly in Asia. *Textilis* has long peduncles from which textile fibers are obtained and it is grown mainly in West Africa.

International Institute of Tropical Agriculture (IITA) has developed high-yielding varieties for both sole and intercropping, with resistance to major diseases, insect pests, nematodes, and parasitic weeds. Researchers are continuing to develop new varieties with high grain and fodder yields that can be used in traditional farming systems. Both USDA and IITA are having rich germplasm of more than 20,000 accessions for further utilization.

2.3 Geographical origin, domestication and distribution

Cowpea (*V. unguiculata*) is one of the most ancient human food sources and has probably been used as a crop plant since Neolithic times (Summerfield *et. al.*, 1974). Carbon dating of cowpea (or wild cowpea remains from the Kimtampo rock shelter in central Ghana) by Flight (1976) is the oldest archaeological evidence. This shows the existence of gathering (if not cultivation) of cowpea by African hunters or food gatherers as early as 1500 BC. About distribution of cowpea, one view is that cowpea was introduced from Africa to the Indian sub-continent approximately 2000 to 3500 years ago (Allen, 1983). Around 300 BC, cowpea had reached Europe and possibly North Africa from Asia. In the 17th century, Spanish took this crop to West India. The slave trade from West Africa resulted in the crop reaching the Southern USA in the early parts of 18th century. Another view goes that Transvaal region of the Republic of South Africa was the center of speciation of *V. unguiculata*, due to the presence of most primitive wild varieties (Padulosi and Ng, 1997).

Ng (1995) postulated that in the process of evolution of *V. unguiculata,* there was change of growth habit from perennial to annual breeding and from predominantly out breeding to inbreeding. During this process, cultivated cowpea (ssp. *unguiculata*) evolved through domestication and selection of the annual wild cowpea (var. *dekindtiana*). There was a loss in seed dormancy and pod dehiscence, corresponding to an increase in seed and pod size in the whole evolution process. The wide geographical distribution of var. *dekindtiana* throughout sub-Sahara Africa suggests that the species could have been brought under cultivation in any part of this region. However, the center of maximum diversity of cultivated cowpea is found in West Africa, in an area encompassing the savannah region of Nigeria, Southern Niger, part of Burkina Faso, Northern Benin, Togo, and the North-Western part of Cameroon (Ng and Marechal, 1985).

Major diversity in cowpea is found in Asia and Africa. Early observations showed that cowpeas in Asia were very diverse and morphologically different from those in Africa. Therefore, both Asia and Africa were thought to be independent centers of origin of cowpea. However, in the absence of wild cowpeas in Asia as possible progenitors, Asian center of origin has recently been questioned.

All the current evidence suggests that cowpea originated in Southern Africa although it is difficult to ascertain where in Africa the crop was first domesticated. Several centers of domestication have been suggested such as Ethiopia, Central Africa, South Africa and West Africa. The working group meeting of the International Board for Plant Genetic Resources on *Vigna,* held in New Delhi in 1981 recommended collection of

both wild and cultivated forms of cowpea from Southern Africa, Zimbabwe, Transvaal and Natal based on distribution of diverse wild cowpeas in these regions. East and Southern Africa are considered as the primary region of diversity and West and Central Africa were considered the secondary centers of diversity. India in particular and Asia in general had been proposed to be the third center of diversity. Recent investigations by the International Institute of Tropical Agriculture (IITA) in collaboration with Instituto del Germoplasmo (CNR) Bari, Italy, strongly indicated that the region encompassing Namibia, Botswana, Zambia, Zimbabwe, Mozambique, Swaziland and South Africa have the highest genetic diversity in respect of primitive wild forms of cowpea. Some very primitive species were observed in the Transvaal, Cape Town and Swaziland. Based on this, it has been suggested that Southern Africa may be the origin of cowpea and from there primitive forms moved to other parts in Southern and Eastern Africa, and from there to Asia and West Africa.

Cowpea was known in India before Christ, dating back to 150 BC. So, cowpea might have moved from East Africa to Asia more than 2000 years ago where human selection led to modified forms of cowpea, different from Africa. It has been suggested that cowpea probably moved from Eastern Africa to India before 150 BC, to West Asia and Europe about 300 BC and to Americas in 1500 AD. Since Western Asia and Europe do not have desired climatic conditions for cowpea, not much variability and selection occurred as it happened in South Asia and South East Asia where small seeded and vegetable cowpeas were selected. Probably, the wild cowpeas with very small seeds were distributed by birds in East and West Africa much before Christian Era and therefore the presence there is of great diversity and secondary wild forms. Selections for larger seeds and better growth habits from natural variants in wild cowpeas by humans, must have led to diverse cultigroups and their domestication in Asia and in Africa. Distribution of different species of cowpea is given as following.

- *V. unguiculata* cv.gr. *cylindrical*

  Distribution: Native to India and Sri Lanka and widely cultivated in tropical areas, as in East Africa. It is more common in Asia and exists here with more cultivars.
- *V unguiculata* cv.gr. *sesquipedalis*

  Distribution: Native to India or Africa, Yard long beans is mostly cultivated in the Far East (Bangladesh, India, Indonesia, Pakistan, Philippines). It is also taken in the Caribbean, and to lesser extent in Africa.
- *V. unguiculata* cv.gr. *unguiculata*

Distribution: Native to Africa and Asia, and widespread in Africa. It spread by the way of Egypt or Arabia to Asia and the Mediterranean. Now it is widely cultivated through- out the tropics and subtropics. Steele (1972) agrees on a solely Ethiopian center of origin, followed by subsequent evolution predominantly in the ancient farming systems of the African Savanna.

2.4 Relations between cultivated and wild cowpea

2.4.1 The progenitor of cultivated cowpea

Pasquet (1996) reported, cultivated accessions are genetically similar to wild annuals (Nei's distance median is 0.154) and ssp. *pubescence* (Nei's distance median is 0.202), but half a dozen loci distinctly separate cultivated accessions from ssp. *pubescence*. This proximity justifies the classification of wild annuals (var. *spontanea)* and cultivated cowpea (var. *unguiculata)* under ssp. *unguiculata*, as Lush (1979) suggested. Var. *spontanea* thus constitutes the most likely progenitor of cultivated cowpea.

2.4.2 The bottleneck

The bottleneck between wild and cultivated cowpeas seems great. Its importance is lessened if one considers that perennials could be treated as distinct species according to their genetic distances. With legumes of neighbouring genera, the variability observed in the wild forms by Schinkel and Gepts (1989); Koenig and Gepts (1989); Potter and Doyle (1992) corresponds to that observed in the var. *spontanea* alone. So, if one takes ssp. *unguiculata* only, the bottleneck is less impressive. It is, nevertheless, a fact that the variability of cultivated forms alone is poor compared to related legumes or to all cultivated plants (Doebley, 1989). This pronounced bottleneck is a second reason for proposing single cowpea domestication.

2.4.3 Discrepancy between wild and cultivated cowpea

There is an isoenzymatic shift between wild and cultivated forms, as two loci clearly separate them. Nei's distances between wild and cultivated are greater than the distances between cultivated forms and the distances between wild forms themselves Furthermore, this gap is confirmed in the cDNA study (Vaillancourt and Weeden 1992). Such discrepancies are fairly rare in cultivated plants, but not without precedent Doebley (1989). Vaillancourt and Weeden (1992) have suggested Nigeria as a center for domestication, but their analysis was based on only 32 cultivars. Only two cDNA patterns

were observed. One was found nowhere among the 26 wild accessions studied and the other in two Nigerian accessions, NI 951 and NI 991. But the morphology of these two accessions indicated that they could be of weedy types resulting from hybridization between wild and cultivated plants. Both cultivated form patterns could exist among wild forms in an area, such as North-East Africa, which has been sampled very little or not at all.

Pasquet (1996) reported from the study on genetic organization and domestication of cultivated cowpea that the evolutionary scheme of cultivated cowpea has become clearer, and there are many reasons for proposing a hypothesis of unique domestication in North-East Africa. However, the shift between wild and cultivated forms still needs to be explained, and the real progenitor among var. *spontanea* still needs to be found.

2.5 Production statistics

2.5.1 Worldwide cowpea production

The important cowpea growing countries are Nigeria, Niger Republic, Mali, Burkina Faso, Senegal, Ghana, Togo, Benin, Cameroon, and Chad in Central and West Africa; Sudan, Somalia, Kenya, Malawi, Uganda, Tanzania, Zambia, Zimbabwe, Botswana, South Africa and Mozambique in East and Southern Africa; Bangladesh, China, India, Indonesia, Korea, Myanmar, Nepal, Philippines, Sri Lanka and Thailand in Asia; and Brazil, Cuba, Haiti, USA, and the West Indies in Central and South America.

According to FAO (2006) about 7.56 million tons of cowpea seeds are produced worldwide annually on about 12.76 million hectares. Sub-Saharan Africa accounts for about 70 per cent of total world production. Hay yields are 5 metric tons/ha. The estimated annual nitrogen fixation is 73-354 kg/ha with a global average of 198 kg/ ha (double that of Soybean). The available data on area, production and average yield of cowpea seed in 11 important cowpea-growing countries totals up to 11.3 million hectare and 3.6 million tons. This data indicates that a substantial part of the cowpea production comes from only a few countries. Nigeria is the largest producer and consumer of cowpea with about 5 million ha area and about 2.4 million tons production annually. Niger Republic is the next largest producer with 3 million ha and over 0.35 million tons production. North-East Brazil grows about 1.5 million ha of cowpea with about 0.492 million tons production which provides food to about 25 million people. In the Southern USA about 0.040 million ha of cowpea is grown with an estimated 0.045 million tons annual production of cowpea seed and a large amount of frozen green cowpeas. India is the largest cowpea producer in Asia together with Bangladesh, Indonesia, Myanmar,

Nepal, Sri Lanka, Pakistan, Philippines, Thailand, and other far Eastern countries; there may be over 1.5 million hectares under cowpea in Asia. Yield of different cultigroups of cowpea are given as following.

- *V. unguiculata* cultigroup *cylindrical*

  Yield of grain is 1,390-1440 kg/ha. In India some cultivars yield only 900- 1000 kg seed/ha. *Catjang* is a very important crop in India and Sri Lanka, and in some tropical African areas.

- *V. unguiculata* cultigroup *sesquipedalis*

  Yields vary with size of beans and frequency of picking. In the Philippines, yields of green pods are 4 to 5.5 MT/ ha. Yard long beans form an important vegetable crop in South Eastern Asia, particularly with Chinese market gardeners, grown also in the West Indies.

- *V. unguiculata* cultigroup *unguiculata*

  Yields vary with cultivars, climate, soil and culture. Yields of beans in the tropics: 400-600 kg /ha; in US 1000-1500 kg/ha, but up to 3000 kg/ha in California.

2.5.2 Cowpea production in India

In India, cowpea is still a minor crop and is grown only in some parts of Rajasthan, Gujarat, Maharastra, Karnataka and Tamil Nadu. It has a great potential for sustainable agriculture in marginal lands and semi arid regions of the country. Though, accurate data on cowpea area and production are not available, it is estimated that about 6.5 lakh hectare is under different forms of cowpea (Singh *et. al.*, 1997) out of which 3 lakh hectare is under fodder cowpea. The average yield of cowpea beans has been in the range of 775 to 1006 kg/ha seed. The average yield of cowpea grain is low at about 3 q/ha. The productivity of green fodder cowpea is about 25-45 t/ha. The largest area under this crop is in Rajasthan where it is cultivated in 1.20 lakh hectare area with a production of 43.2 thousand MT of grain (1996-97). The crop besides being adapted to arid regions of Western Rajasthan is suitable for late sowing in the event of delayed monsoon. More than 50 per cent of cowpea area is in 11 districts of Western Rajasthan, except in zone III (Zone III a- Semi arid Eastern plain includes Ajmer, Jaipur, North Western Tonk and a part of Sawai Madhopur district. Zone III b i.e. Flood prone Eastern plain – South Eastern Alwar, Bharatpur and North Eastern Sawai Madhopur district). The area, production and productivity were found to be decreasing over the years.

2.6 International status of cowpea improvement

2.6.1 Plant genetic resources

There are large and diverse *Vigna* collections held in several international centers. The large numbers of unique accessions have been added to the **USDA** cowpea germplasm collection since 1988 through the University of California. Efforts are currently underway at the Plant Introduction Station in Griffin, Georgia, to develop the methodology identify duplicates (synonyms).

The International Board for Plant Genetic Resources' (IBPGR) publication 'Genetic Resources of *Vigna* Species' (AGPG:IBPGR/81/82) assigned the following crop priorities (each entry in order of need) for exploration and collection.

- *Vigna unguiculata* (cultivated forms)

  Fernando Po, Mozambique, Zimbabwe Botswana, Lesotho, South Africa, Swaziland Central African Republic, Zaire, Angola, Congo, Gabon, South-East Asia and China.

- *Vigna unguiculata* (wild forms)

  South Africa (Natal and Transvaal), Zimbabwe, East African and Zambezian phytogeographical zones.

The International Institute of Tropical Agriculture (IITA) has cowpea base collection of 12,000 to 13,000 accessions that is larger than the current collection of USDA. Collectively IITA houses over 16000 cultivated and wild accessions of cowpea that cover a wide spectrum of growth habits, environmental responses and varying pest and disease susceptibilities. It is this precious source of material that serves as the essential foundation for the breeding of new improved varieties. The IITA collection is a very important collection, and major effort needs to be made to store duplicate samples in some other country also from where the material is easily accessible.

The **University of California** at Riverside has an appreciable collection of cowpea germplasm of about 5,000 accessions that was obtained from the USDA, IITA, and different countries as part of the Title XII Bean/Cowpea Collaborative Research Support Program. The characteristics of different germplasm are given as following.

- *V.unguiculata* cv.gr. *cylindrical*

  Germplasm: This cultivar does well in Puerto Rico. It is a grain variety, with erect vigorous growth habit, short growing period, nearly uniform maturity; pods do not shatter at maturity, relatively resistant to attack by aphids and bean fly, and fairly drought resistant. This has been assigned to the Indo-China-Indonesian centers of Diversity.

➤ *V. unguiculata* cv.gr. *sesquipedalis*

Germplasm: In Hong Kong, cultivars are divided into two groups being as Green podded forms 45-90 cm long; and White podded forms with very pale green pods, up to 45 cm long. Yard long is a good cultivar; in Trinidad, the cultivar 'Long White' imported from Hong Kong has given good results. Bush cultivars are being developed in the Philippines. Assigned to the African and Hindustani Centers of Diversity, Yard long bean thereof is reported to exhibit tolerance to laterite, photoperiod, poor soil, slope and virus. 2n=22, 24.

➤ *V. unguiculata* cv.gr. *unguiculata*

Germplasm: The most extensive collection of germplasm is at IITA (over 7000 accessions in 1975). Cowpea cultivars may be grouped in the following manner for the US: Crowder peas, seeds black, speckled brown, or brown eyed, crowded in pods, seeds usually globose, 'Brown Crowder' a good cultivar in Puerto rico: 'Black eyed' seeds white with black eye around hilum, not crowded in pods. Extensively grown in California and South Eastern US and Puerto rico; 'Cream cultivars: seed cream colored, not crowded in pods; intermediates between Crowder and Black eyed types, as Purple Hill with deep purple mature pods and buff or maroon eyed seed; forage cultivars: as New era useful also for dry seeds in other geographical locations, eg ., Western Africa. Other standard cultivars are 'Block', 'Braham', 'Early Bluff', 'Iron', 'Taylor', and 'Victor'. 'Gubgub' is an excellent table cultivar assigned to the African and Hindustani Centers of Diversity, cultivars thereof are reported to exhibit tolerance to aluminium, drought, high pH, heat, laterite, low pH, nematodes, poor soil, shade, slope, virus, weeds and wilt. 2n=22.

2.6.2 Conventional methods of cowpea improvement

Cowpea characterization

Cowpea yields are low because the environments where they are produced are characterized by various abiotic and biotic stresses. However, even under optimal conditions, the yields are variable and unpredictable, partly due to variability in the growth and development of individual plants. Understanding the extent, distribution and nature of this variation would be useful in the development of cowpea genotypes with both increased yield potential and improved adaptation to environmental stresses. Phenotypes and genetic diversity can be evaluated using morphological characters, biochemical or molecular markers.

2.6.3 Morphological characters

Traditionally, genetic diversity evaluated in crop species are based on differences in morphological characters and qualitative traits, (Schut *et al.*, 1997). Probably due to the fact that the assays of qualitative traits do not need any sophisticated equipment or complex experiments, they are generally simple, rapid and inexpensive to score. It has been used as a powerful tool in the classification of cultivars and also to study taxonomic status.

Morphological traits continue to be the first step in the study of genetic relationships in most breeding programmes (Cox and Murphy, 1990; Van Beuningen and Busch, 1997) because of (1) the existing data bases on the germplasm collection or breeding stocks can often be used for genetic analysis; (2) statistical procedures for morphological trait analysis are readily available; (3) morphological information is essential in understanding the ideotype performance relationships; and (4) explanation of heterosis may be enhanced if morphological measures of distances is included as an independent variable. In cowpea breeding programmes, the major emphasis has been on the collection and conservation of genetic pools.

However, the use of morphological traits depends on biochemical traits and most of them are ambiguous descriptors and have limited use for cultivar identification (Stegemann, 1984; Zacarias, 1997). Many of the morphological traits are also difficult to analyze because they do not have the simple genetic control assumed by many in genetic models (Tanksley *et al.* 1989). Genetic relationship evaluation among germplasm using morphological characteristics are lengthy and costly processes (Cooke, 1984). The genetic control of many morphological characters is assumed to be complex, often including epistatic interactions, and has often not been elucidated (Smith, 1986). Many morphological markers are recessive and therefore only expressed in the homologous condition. Most elite cultivated and breeding materials do not abound with readily observable morphological markers, a large number of which have deleterious effects on agronomic performance (Smith, 1986).

USDA has evaluated the genetic resource of cowpea for many important traits including inheritance of economically important cowpea traits, identification of new sources of tolerances to herbicides, seedling chilling, Al toxicity, Ca deficiency, heat stress, and drought stress, identification of new sources of resistances to insects and nematodes, mechanisms of virus resistance, salt tolerance, ways to improve protein quality, ways to improve photosynthetic and nitrogen fixation efficiencies and the

development of improved procedures to evaluate various cowpea traits (Adams *et. al.* 2003).

International Institute of Tropical Agriculture, IITA scientists have developed high-yielding varieties that are early or medium maturing and characterized by consumer-preferred traits such as large seed size and color. Cowpea lines that mature in about 60 days after planting have resulted from breeding activities. A number of the improved varieties have resistance to some of the major diseases, insect pests, nematodes, and parasitic weeds. They are also well adapted to sole or intercropping. Improved breeding lines distributed to collaborators in over 60 countries under the Cowpea International Trials (CIT). Some of these lines have been released as improved cowpea varieties or used in breeding programs in the different countries. In the over 35 years that IITA scientists have worked on cowpea, total cowpea production worldwide has increased from 1.2 million to more than 7.5 million tonnes per year in about 12.7 million hectares.

IITA Scientists are working in collaboration with the cowpea project for Africa (PRONAF), which is also coordinated by IITA. Also collaboration is there with the Bean/Cowpea CRSP and the Network for Genetic Improvement of Cowpea for Africa (NGICA).

Dingkuhn *et al.* (1999) reported that there is need of reorientation of breeding objectives in recent times towards combining traditional with modern crop characteristics, to achieve better weed competitiveness or timely maturity at the end of the wet season through photoperiod-sensitivity. Clerget *et al.* (2004) has called for the increased use of native donor materials.

2.6.4 Biotic stress

Diseases such as anthracnose, bean rust, CBB and bean common mosaic and abiotic stresses such as drought and low soil fertility were reported to be important constraints to bean production wherever the crop is grown (Schwartz *et al.*, 1996; Van Schoonhoven and Voysest, 1989; Wortmann *et al.*, 1998). Resistance to pests is particularly important because it can enhance productivity, product quality and environmental conditions as well as decrease input costs thereby enhance profits. A reduction in applications of pesticides is an important goal for cowpea research programs in Africa and the United States. New cultivars also facilitate the extension of improved farming systems.

2.6.4.1 Resistance to flower thrips

Flower thrips were reported to be major insect pest of cowpea in the Savanna zone and a moderate insect pest in the Sahelian zone of Africa (Hall *et al.*, 1997). In Senegal, 'Melakh', accession '58-77' and breeding line 'ISRA- 2065' have shown partial resistance to flower thrips in trials comparing grain yield with and without insecticide applications. The resistance was slightly greater than that of 'TVx 3236'.

2.6.4.2 Resistance to cowpea aphid

Seedling resistance to cowpea aphid was identified in cowpea accessions by IITA and other organizations 20–30 years ago. Aphid-resistant lines from IITA included 'TVu 86', 'TVu 801', and 'TVu 3000' (IITA, 1984). Since that time, these sources of resistance have been used extensively in cultivar development at IITA (Singh *et. al.*, 1997) and in several national cowpea-breeding programs in Africa, including in the development of 'Melakh' for the Sahelian zone. Other sources of cowpea aphid resistance include those discovered in Kenya (Pathak, 1988) and in India (Chari *et al.*, 1976). Resistances present in the African and Indian lines have not been effective against those biotypes of cowpea aphid occurring in California that have been tested (Abdalla, 1992; Martyn, 1991). There has been extensive screening to identify resistance to California biotypes of cowpea aphid. 'IT84S-2049', a source of broad-based root-knot nematode resistance, was observed to have moderate resistance to cowpea aphid in greenhouse seedling tests (Abdalla, 1992).

Crosses have been made to transfer the cowpea aphid resistance of 'IT93K-503-1' and 'UCR 779' to green manure/cover crop and dry grain types of cowpeas adapted to California.

2.6.5 Abiotic stress

2.6.5.1 Drought

Drought is a common cause of yield loss, with two types of drought distinguished. Beaver and Rosas (1998) found that selection for earlier flowering, a greater rate of partitioning and a shorter reproductive period permitted the selection of breeding lines having one week earlier maturity without sacrificing yield potential. These combinations of phenological and physiological traits contribute to the genotypic avoidance of terminal drought. Researchers in Mexico found that selection for high seed yield potential under irrigation may permit indirect selection for greater tolerance to terminal drought Resistance to drought is confounded by root health and vigor and with resistance to soil-

borne root rot pathogens such as *Fusarium spp.* and *R. solani* (Navarrete-Maya and Acosta-Gallegos, 1999). The lack of adequate levels of root rot resistance contributes to the increased susceptibility of bean cultivars to intermittent drought in highland production regions. Likewise, tolerance to terminal drought is associated with resistance to ashy stem blight caused by *Macrophomina phaseolina* (Tassi) Goid.

Advances in cowpea breeding for drought tolerance

Significant progress has been made at International Institute of Tropical Agriculture (IITA) in an attempt to develop cowpea drought tolerant genotypes. For example early-maturing cowpea varieties that escape terminal drought has been developed (Singh, 1987).

Different drought tolerant lines have also been identified. Those that cease growing as soon as drought stress is imposed, probably to conserve moisture and survive for 2-3 weeks and those that mobilize moisture from lower leaves and remain alive for a longer time. Consequently, these varieties have a better regeneration potential than others do.

A simple technique, using wooden boxes, was developed to screen cowpea germplasm lines at seedling stage, and test their field performance at mature stage under conditions of water deficit. The wooden box technique was found to be more appropriate for breeding programmes in developing countries. Efforts are also being made to combine deep root systems with drought tolerance, to enhance adaptation of cowpeas to low rainfall areas (Watanabe, 1993).

2.6.5.2 Heat

In lowland environments, terminal drought stress was found to aggravate by high temperatures. In Central America and the Caribbean, breeders have focused on heat as a constraint to expanding bean production in the lowland tropics. They have made significant progress in the development of bean cultivars with improved levels of heat tolerance (Rosas *et al.*, 2000). Indeterminate Jamaica Red is currently being used to improve the heat tolerance of kidney beans in the USA (Miklas *et al.*, 2000).

Heat tolerance during reproductive development

Cowpeas are reported to be very sensitive to high night temperatures during reproductive development (Hall, 1992; 1993). In California, heat-sensitive cowpea cultivars, such as 'CB5', were shown to exhibit 4–14 per cent decreases in pod set and

grain yield for each 8° C increase in daily minimum night temperatures (Nielsen and Hall, 1985; Ismail and Hall, 1998). Low pod set was associated with damage to anthers by high night temperature occurring 9–7 days before anthesis, which resulted in male sterility (Ahmed *et. al.*, 1992). Two weeks or more of consecutive or interrupted hot nights during the first 4 weeks after germination also caused complete suppression of floral bud development such that plants do not produce any flowers (Ahmed and Hall, 1993). The suppression of floral buds caused by high night temperatures only occurred in long-day conditions (Patel and Hall, 1990). Most cowpea accessions either produced no flowers under hot long-day conditions or if they produced flowers they did not set any pods (Patel and Hall, 1990; Ehlers and Hall, 1996).

Genetic lines were bred that have a recessive gene conferring heat tolerance during early floral development, permitting the plant to produce flowers when subjected to heat (Hall, 1993). Marfo and Hall, 1992; Hall, 1992; Hall, 1993 also observed a dominant gene and some minor genes that enhance the ability of the plant to set pods during hot weather.

An approach used to incorporate this set of heat-tolerance genes involved, subjecting F2 plants to high night temperatures and long days in very hot field or greenhouse conditions and selecting plants that produce flowers and set many pods per peduncle (Hall, 1992, 1993, 2003). F2 selection fixed the ability to produce flowers in most but not all lines; however, ability to set many pods required several generations of family selection. Six heat-tolerant lines were bred, including 'CB27', and were shown to have greater grain yield in fields with hot weather in California than six heat-sensitive lines with similar genetic backgrounds, including cultivar, 'CB5' (Ismail and Hall, 1998). In greenhouse conditions these heat-tolerant lines had high grain yield under hot conditions in either the long days typical of subtropical zones or the short days typical of tropical zones (Ehlers and Hall, 1998). However, grain yield of heat-sensitive lines was not reduced as much by high night temperature under short days as it was under long days (Ehlers and Hall, 1998). Under short-day tropical conditions in Northern Ghana and Senegal with very high night temperatures, no differences in grain yield were observed between the six heat-tolerant and six heat-sensitive lines but grain yields were low for all lines (Hall *et al.*, 2003).

Indirect selection for the three major physiological traits affecting yield, namely plant biomass, harvest index (HI), and days to maturity, showed an improved yield (Wallace *et al.*, 1993).

2.6.6 Isozymes

Isozymes are enzymes that share a common substrate but differ in electrophoretic mobility. Isozymes are also used as biochemical markers. Isozymes have long been used because the technique is very robust and simple in that the protein extraction and the running of protein molecules on the gel is simple, large numbers of samples can be run in very short time and the bands are expressed co-dominantly. Direct measures of genetic similarity between individuals have been determined from isozyme markers in many crop plants (Brown, 1979). Isozymes have largely been used in cowpea improvement programmes with emphasis on populations, taxonomy, genetic relationship and diversity studies.

Isozyme application in cowpea

Vaillancourt and Weeden (1993) showed the lack of isozyme similarity between *Vigna unguiculata* and other species of genus *Vigna*. UPGMA cluster analysis was performed and the range of genetic distance among species of subgenus *Vigna* was greater than previously reported in most plant genera. None of the species included in the survey is a close relative of *V. unguiculata*, as shown by the results.

Panella and Gepts (1993) studied the genetic relationships within *Vigna unguiculata* based on isozyme analyses. In general, results of this study concurred with the taxonomic classification within *V. unguiculata* and provided a strong indication that a severe genetic bottleneck occurred during the domestication process of cowpea.

In cowpea -weed complex all over Africa, the isozyme marker Amp2102 (Pasquet, 1999) was utilized and there appears to have been a single domestication event, the genetic similarity of some of the wild accessions to the domesticated group was result of post-domestication gene flow between wild and domesticated forms due to their sympatric distribution. Such accessions "weedy" types were not found in natural undisturbed habitats, instead they were found usually in disturbed habitats such as field margins. This type of habitat seemed to preclude domestication in that part of the continent, unless the actual progenitor became extinct or only survived as weedy types in that region. Although markers were absent in wild variety and present and numerous in-domesticated types, domesticated frequencies for these markers were usually below 0.1 and did not reach beyond 0.30. Therefore, cowpea domestication from a progenitor from Eastern or Southern Africa is also unlikely. This is a clear answer that isozyme studies were unable to give (Pasquet, 1999) a more conclusive answer regarding actual domestication center in Western or North-Eastern Africa and awaits further data also,

markers near or at genes for the domestication syndrome need to be identified; analysis of genetic diversity in crops and their wild progenitors using these markers provides a more consistent separation between domesticated and wild types, which in turn may help identify the wild populations most closely allied to the crop.

Pasquet (1999) also studied genetic relationships among subspecies of *Vigna unguiculata* L. (Walp) based on allozyme variation. In this study, genetic variations in 199 germplasm accessions of wild and cultivated cowpea were evaluated using an allozyme analysis. The results from this survey showed that wild cowpea exhibits genetic variation perfectly fitted with the existing morphological classification. The cowpea gene-pool is characterized by its unusually large size. It encompasses taxa (ranked as subspecies) that could be considered as different species considering the high genetic distances observed between accessions belonging to different taxa. These subspecies can be classified into three groups characterized by their breeding systems: perennial outcrossers, perennial out-inbreds, and inbred annuals. Allozyme data confirmed this grouping. Perennial outcrossers look primitive and are more remote from each other and from perennial out-inbreds. Within this large gene-pool, mainly made of perennial taxa, cultivated cowpeas (ssp. *unguiculata* var. *unguiculata*) form a genetically coherent group and were closely related to annual cowpeas (ssp. *unguiculata* var. *spontanea*) which may include the most likely progenitor of cultivated cowpeas.

Reis and Frederico (2001) studied genetic diversity in Cowpea (*Vigna unguiculata*) using isozyme electrophoresis. Accessions of cultivated cowpea (*V. unguiculata* ssp. *unguiculata* cv. gr. *unguiculata*, cv. gr. *sesquipedalis and* cv. gr. *biflora*) from different countries were evaluated for isozyme variability. Zymograms were obtained by polyacrylamide gel electrophoresis and eight enzyme systems were studied. Cowpea accessions studied were characterised by very low genetic diversity. Accessions were monomorphic for almost all loci tested except for the esterase enzyme system. Comparative analysis of esterase zymograms made it possible to identify some of the accessions studied. However, the cultivated groups *biflora* and *sesquipedalis* could not be distinguished from one another or from the cv. gr. *unguiculata.*

2.6.7 Cytology

A number of wild species of the genus *Vigna* were examined by J. A. Frahm-Leliveld (1965) as to study their chromosome numbers and mitotic metaphase plate configurations. Both the reported diploid numbers 20 and 22 were found or confirmed in

a number of wild African species and one originating from East Asia. In species with the chromosome number 20 no deviations from this chromosome number were found. The identification of individual chromosomes is generally limited by their extremely small size. Thirty-six cultivars of *V. unguiculata* cv. gr. *unguiculata* and *V.unguiculata* cv. gr. *sesquipedalis* of various tropical and subtropical sources were investigated, together with wild or sub spontaneous types of *V. unguiculata* and some closely allied forms. The diploid chromosome numbers 22 and 24 have been mentioned in literature. The following results have been obtained.

1. A deviation of the chromosome number 22 ranging from 20 to 24 is noted in almost 10 per cent of the cases analyzed. Twenty-four chromosomes were found in the majority of these cases.
2. When comparing the wild and sub spontaneous types and their close allies with the cultivars, deviations in the cultivars decreased by half which points to a stabilizing influence of domestication and selection. In this respect no difference was observed between e.g. the African and American cultivars studied.
3. In some of the *Vigna* species, whether having 20 or 22 chromosomes, there is a considerable difference in shape and size of the entire set, which is independent of the degree of spiralization: in this manner, the Central-and South American types generally were characterized by smaller chromosomes as compared to those in the African and Indian cultivars.
4. The difference was emphasized by the results of grafting combinations between cultivars with large and small chromosome sets.
5. The above-mentioned facts may indicate that the polyphyletic origin of the subtribe Phaseoleae may even be traced in a genus such as *Vigna*.

In plants, polytene chromosomes have been observed in only a few species, and seemed to be restricted to ovary and immature seed tissues, e.g., in *Phaseolus coccineus* and *P. vulgaris*. However, Nagl (1981); Guerra and Carvalheira (1994) observed them in the cells of the anther tapetum of *Vigna unguiculata*. In some species of *Phaseolus* and *Vigna* the polytenics are more clearly defined and, therefore, better suited to the study of this type of chromatin organization. Cytogenetical analysis of the tapetal cells of *Vigna* species has revealed that this tissue can present very peculiar characteristics (Guerra and Carvalheira, 1994).

Adetula,, 1999 studied centromeric banding pattern of mitotic chromosomes in *Vigna vexillata,* accession TVnu 73. The results of chromosome characterization using Leishman C-banding technique showed that the chromosomes mostly exhibited bands at

both the centromeric and telomeric regions. It was reported that these bands will serve, as a valuable marker for the identification of the chromosomes. A chromosome 2 was the most variable and differed from the other chromosomes by the presence of satellite on the short arm. Diploid chromosome number of 22 consisting of 11 pairs of homologues was observed for *V. vexillata.* The homologues chromosomes were arranged in the descending order. The idiogram representing the chromosomes was also constructed.

Cowpea is an important grain legume crop with high protein content. The major constraint to high productivity and long-term storage of cowpea is damage by insect pests. The wild *Vigna* such as *V. vexillata* are known to be sources of genes for resistance. There was incompatibility when crosses were made with the cultivated cowpea, *V. unguiculata* (Adetula, 1999). Basic information on the cytogenetics of the wild *Vigna* is very useful for the successful transfer of desirable traits into the cultivated cowpea. Eleven pairs of homologues chromosomes were identified. The banding pattern of *V. vexillata* (TVNu 73) reported is as follows.

- Chromosome 1 had a centromeric band, a prominent dark band at the terminal end of long arm.
- Chromosome 2 had an interstitial band on the short arm. A prominent dark band is seen at the terminal end of the long arm.
- Chromosome 3 had a centromeric band as well as a telomeric band at the short arm.
- Chromosome 4 had a relatively large distinctive centromeric band.
- Chromosome 5 had two centromeric bands.
- Chromosome 6 had a telomeric band on the short arm.
- Chromosome 7 had only a telomeric band on the short arm.
- Chromosome 8 had only a centromeric band.
- Chromosome 9 had a telomeric band on the short arm.
- Chromosome 11 had a telomeric band only on the short arm.

Comparative study of karyotypes of two *Vigna unguiculata* subspecies was done by Adetula (2006). The chromosomes of two *Vigna* subspecies were individually identified in order to gain insight into variations in the chromosome morphology that may contribute to interspecies cross incompatibility. Diploid chromosome number of 22 was established for *V. unguiculata* (TVu 14476) while *V. unguiculata* ssp. *dekindtiana* varieties *pubescence* was different with mitotic chromosome number of 23. The total lengths of chromosomes ranged from 2.0-5.2 μm. Identification of individual chromosomes was carried out using chromosome length ratio between arms and centromeric positions. The 11 pairs of homologues were classified as metacentric,

submetacentric, sub telocentric and acentric using a centromeric index, which was between 0 and 50. Idiograms were constructed for the two *Vigna* ssp. based on average length of each chromosome.

Crosses between cultivated *Vigna unguiculata* and members of wild *Vigna* were carried out by Agwarwnze (1992) and Adetula (1999). The results showed that fertilization did not occur in most of the crosses. Karyotypes of the two genotypes of the *Vigna* species, *Vigna unguiculata* (TVu 14476) and *V. unguiculata* ssp. *dekindtiana* varieties *pubescence* (TVNu 110-3A) were prepared by taking the measurement of the chromosomes from photomicrographs in millimeter. The chromosomes on the photographs were numbered and arranged in order of decreasing length and long-short arm were taken and converted to microns. The chromosomes were paired and compared.

Mitotic chromosome number of 22 was observed in cowpea accession *Vigna unguiculata* (TVu 14476). The chromosome number varied in *V. unguiculata* ssp. *dekindtiana* varieties *pubescence* (TVNu 110-3A). About 20 per cent of the observed cells showed mitotic chromosome number of 23. This is unique and it has been confirmed in the meiotic chromosome by (Adetula, 1999). On the basis of arm ratios, chromosomes of *Vigna* were classified as metacentric, submetacentric, sub telocentric and acentric. The karyotype of TVu 14476 consisted of 7 metacentric, one sub metacentric, one sub telocentric and 2 telocentric chromosomes. The karyotype of TVNu 110-3A consisted of six metacentric, one sub metacentric, two sub telocentric and two telocentric chromosomes.

2.7 National status of cowpea improvement

2.7.1 Plant genetic resources

Cowpea germplasm holding in Genetic Resources (Anon., NBPGR, 2007), Medium term storage of NBPGR, New Delhi of cowpea was 1500 accessions (Annual report 2006-07).

2.7.2 Conventional methods

Pandey and Pawar (2000) conducted a study with a view to developing high yielding, large white seeded varieties of cowpea with determinate growth habit through mutation breeding approaches. Seeds of an early maturing, semi determinate exotic cowpea accession EC 394736 (vegetable/grain type) were irradiated with 250 Gy of

gamma rays. Mutants with determinate or non tendrillar growth habit were isolated in the M2 generation. The stability of mutants was confirmed in the M3 and subsequent generations. Field studies on the yield components of one of the mutants designated as ECM 9902 and the parent were carried out during September – November 2001 BARC Trombay. The mutant with reduced plant height showed superiority in pod number, test weight and seed yield per plant. There was little difference in other parameters like, number of branches, pod length and seeds per pod. The mutant and the parent both matured in 62 days and displayed field resistance to aphids. When compared to one of the high yielding cowpea varieties, V-130, the mutant was found far superior in respect of earliness, seed size yield and reduced plant height. The mutant with several desirable characters like early maturity, large seed size, white seed colour and tolerance to pests and diseases, is being used in crossing programme with elite varieties and other promising mutants.

Haibatpure *et al.* (2003) reported that four lines of cowpea were crossed with six varieties to obtain 24 crosses. 24F1's and 10 parents were grown in randomized block design with three replications in *Kharif* 2001. Heterosis was studied for 10 quantitative characters. In general better performance of hybrids was observed for most of the characters studied. Best heterotic combinations for grain yield over mid parent were TC 2000-2 X GC-2. TC 2000-2 X GC-3 and TC 2000-2 X GC-4. Heterosis in yield seemed to be influenced by heterosis in number of pods/plant, seeds/pod, number of branches/plant and test weight.

Singh and Arora (2003) studied heterosis and inbreeding depression for ten characters, in four crosses of cowpea (*Vigna unguiculata*) namely , CS 55 X CS 39, CS 55 X HFC 42-1, CS 39 X GC-2 and HFC 42-1 X GC-2. Significant positive heterosis was observed for seed yield, which ranged from 50.17 to 263.32 percent over mid parent. The inbreeding depression from F1 to F2 for seed yield ranged from 8.96 to 53.01 percent. All the crosses exhibited significant and desirable heterosis both over MP and BP for seed yield. Two crosses namely CS 39 X GC-2 and HFC 42-1 X GC-2 could be worth exploiting for having high heterosis and less depression, respectively, for improving yield and it's components in cowpea.

Nagaraja *et al.* (2003) studied the segregating populations of three crosses of cowpea i.e. C 152 X APC 412, TVX 944 - 02E X APC 225 and KBC-2 X APC 1452, which were advanced by pedigree, bulk and single seed descent methods of selection from F4 and F5 to and F6 generations during Kharif 1999-2000 at the university of

Agricultural Sciences, Bangalore, under AICRP on Arid Legumes. In addition to the above methods, two more methods were included in the study by selecting top 15 per cent of the plants based on seed yield per plant in unselected population of bulk and SSD in F4 and F5 generations to obtain sowing material for selected bulk and selected SSD methods. These methods were compared for their efficiency in obtaining high mean seed yield of top 15 percent segregants and percentage of segregants superior to standard check (best parent among all the crosses i.e. KBC-2 , also the ruling variety in the area). In both F5 and F6 generations advanced, selected populations of pedigree, bulk and SSD followed by unselected SSD showed relatively superior performance over unselected bulk population method in realizing promising segregants having high mean values and higher percentage of segregants superior over check variety for majority of yield and yield attributing characters.

Parmar *et al.* (2003) studied association analysis for grain yield and contributing characters in cowpea. Thirty-two advanced breeding lines of cowpea were evaluated during Kharif 2000 in a randomized block design with three replications. Observations were recorded on different agronomic characters including grain yield. Estimates of the phenotypic and genotypic correlation coefficients, in general exhibited similar trend. Grain yield showed significant positive association with number of clusters/plant and pods/plant at phenotypic and genotypic levels. Other significant positive genotypic correlations were between days to flower with days to maturity (0.467) and plant height (0.436), days to maturity with plant height (0.563), pod length (0.663) with seeds/pod (0.429), plant height with test weight (0.368), branches/ plant with clusters /plant (0.511), clusters/plant with pods/plant (0.949) and pods/cluster with pods/plant (0.649). Pods/ plant registered the highest direct effect on seed yield, followed by clusters/plant and seeds/pod, whereas, test weight, days to flower and pods/cluster exhibited moderate positive direct effects. The indirect effects of branches/plant via seeds/ pod were also positive and high. Based on the findings it is suggested to lay more emphasis on pods/plant, clusters/plant, seeds/pod, test weight and pods/cluster in selection programmes aiming to improve grain yields in cowpea.

Misra *et. al.* (2003) evaluated a set of 740 germplasm accessions of cowpea including both indigenous and exotic origin, for 25 descriptors at the Division of Genetics, IARI during Kharif 2001. A wide range of variation was observed in almost all the characters under study. Many promising genotypes like C405, C483, C538, C566,

C442, C 515, C 557 have been identified which can serve as potential donors for major economic traits.

Kumar *et al.* (2001) evaluated fifty genotypes of cowpea to estimate the variability, heritability, genetic advance, correlations and path coefficients for ten morphological traits, during *Kharif*, 2001. Maximum range of variation was noted for plant height followed by days to maturity, days to 50 per cent flowering, pods per plant and seed yield per plant. GCV and PCV values were highest for seed yield, followed by pods per plant, 100 seed weight and clusters / plant. High heritability coupled with high GA was observed for seed yield /plant, pods/ plant and clusters/plant. Correlation studies revealed significant and positive association of seed yield /plant with clusters / plant, pods/ plant and 100 seed weight and days to maturity had the maximum and desirable direct as well as indirect effects on seed yield per plant. The results of present study suggested that selection based on above three characters might bring simultaneous improvement in seed yield.

Henry and Mathur (2003) studied varietal divergence in cowpea. Twenty three varieties of cowpea of different centers were evaluated under rain-fed conditions during monsoon season of 1997 and 1998. Wards method of hierarchical cluster analysis was applied to group the varieties. The quantum of rainfall received during the cropping season of 1997 and 1998 varied considerably. Twenty three cowpea varieties were classified into 4 clusters in 1997 and into 3 clusters in 1998. The maximum inter cluster distance was between cluster I and IV in 1997 and cluster I and III in 1998. The varieties falling in cluster I in both the environments were early in maturity and some were high yielding in stress environment of 1998. These high yielding varieties with earliness in maturity could be crossed with bold seeded varieties with medium late maturity of cluster IV in 1997 and cluster III in 1998 to get high yielding, early maturing and bold seeded varieties suitable for arid region/ rainfed areas.

Chauhan *et al.* (2003) studied combining ability in cowpea. Combining ability variances were estimated by mating four lines developed through mutagenesis and six elite cowpea varieties as testers in a line X tester fashion all the characters had significant differences (except branches / plant in testers) among lines and testers. Among the lines TC 2000-4 proved the good general combiner for earliness, maturity, pods/plant, pod length, 100 seed weight and seed yield. Non additive effects were relatively more

important for seed yield and most of its components. Intercrossing between best cross combinations for seed yield, earliness and dwarf ness is advocated to obtain better segregates.

Kavita *et. al.* (2003) studied stability analysis for grain yield in cowpea. Twenty one genotypes of cowpea were evaluated for stability of grain yield/plant. All the genotypes differed significantly revealed enough genetic variability for grain yield. Linear component (59.96 per cent) of genotype X environment interaction was reported to be higher than that of nonlinear. In all, ten genotypes had above average mean, average responsiveness and were stable for grain yield hence their use in future breeding programmes aimed at stable grain yield in cowpea is advocated.

Singh (2003) studied stability of cowpea lines under weather conditions of semi arid region. Analysis of variance indicated significant differences between genotypes. The interaction sum of squares of genotypes X years was also highly significant indicating the effect of environment on character expression. The stability analysis indicated that none of the genotypes was found to be stable. A comparison of yield data over the years with weather parameters was done which indicated that the amount of rainfall and its distribution affected the relative ranking of genotypes.

Henry (2003) studied genotypes X environment interactions for seed yield in cowpea. Twelve important genotypes of cowpea were evaluated for their performance for 5 years (1994-1998). The results revealed significant variation for genotypes and genotype X environment interactions for the seed yield. V-585 was the only genotype which indicated a unit responses under fluctuating environmental conditions (b=1.01) which was medium late in maturity, however, this was not the highest yielder. Genotypes GC-3 was especially found suitable for adverse weather conditions. However, under such situation genotypes viz. GC8910 and GC-8926 had better yielding ability. Genotypes viz. CAZC-9, CAZC -10, CAZC-11, and CAZC –W were found to respond more to favourable growing conditions (b > 1.0) and had high yielding ability. These were medium to medium early in maturity. The exploitation of above genotypes in breeding programme will lead to the development of most desirable genotypes for dry land areas.

2.7.3 Biochemical studies

Isozyme application in cowpea

Ganguly *et. al.* (1990) carried out a study on the superoxide dismutase activity in resistant and susceptible cowpea cultivars inoculated with root knot nematode, *Meloidogyne incognita* using isozyme. Superoxide dismutase activity increased in resistant cultivars at all stages of observation. Electrophoretic analyses showed that the isozymes did not vary in number or electrophoretic mobility.

Raman and Dhileepan (1993) studied two oxido reductases and polyphenol oxidase from cowpea infected by *Meloidogyne incognita* race one. Polyacrylamide gel electrophoresis (PAGE) analysis of polyphenol oxidase showed that four new isozymes were produced in roots seven days after inoculation. They were also present after 14 days although their rm values differed. Phenol concentration also increased with infection.

Chandra *et al.* (1999) performed a study, the determination of phenylalanine ammonia lyase (PAL) activities leading to decline in disease progress caused by *Rhizoctonia solani* after application of salicylic acid (SA). Two applications of 1.4 mM SA (pH 6.5) followed by inoculation with *Rhizoctonia solani* resulted in a quantitative change in polyphenol oxidase (PPO), peroxidase (PRX) isoforms and increase in PAL activities from 4.38 to 19.48 unit g^{-1} (FM) h^{-1} in Bundel-1, UPC-4200 and IFC-902 cowpea genotypes. Increase in PAL activities was further observed specifically in UPC-4200 when plants were exposed with *Rhizoctonia solani* spores. Total soluble proteins did not change after SA treatment, however they were significantly increased in SA sprayed-inoculated UPC-4200 genotype of the ten detected isoforms of polyphenol oxidase, isoforms 7 and 10, and isoform 4 of peroxidase showed increased activities by SA application. The disease symptoms measured as areas under progress curve (AUDPC) indicated less A value in SA sprayed Bundel-1 and UPC-4200 genotypes over their controls.

Selvi *et al.* (2003) studied genetic diversity analysis in genus *Vigna* based on morphological traits and isozyme markers. The genetic variation among 52 accessions of *Vigna* species was studied, that included 15 accessions of *V. unguiculata*, 15 accessions of *V. mungo*, 19 accessions of *V .radiata*, and one accession each of the wild species *V. aconitifolia, V. trilobata*, and *V. radiata* var. *sublobata* belonging to the subgenera *Ceratotropis* and *Vigna*. These were investigated using morphological traits (25 qualitative traits and 14 quantitative traits) and five isozyme markers. The clustering based on morphological traits grouped the various subgenera of *Vigna* into one cluster but failed to reflect the real genetic relationship among different species. The clustering based

on the isozyme variations (superoxide dismutase, aspartate amino-transferase, isocitrate dehydrogenase, peroxidase, and α -esterase), however, revealed a truer taxonomical relationship by grouping *Ceratotropis* and *Vigna* species into two distinct clusters. From the present study, it is concluded that variation in isozymes can be exploited to understand the extent of the genetic diversity and relationship among the accessions of *Vigna*.

Githiri *et al.* (1996) studied genetic linkage of the aphid resistance gene, *Rac*, in cowpea. Several researchers have reported possible utilization of isozyme markers in plant breeding (Soltis and Soltis, 1989). Isozyme markers are important in marker-based selection in that, unlike morphological markers, they are expressed in a co-dominant manner and can thus distinguish between homozygotes and heterozygotes, need only a small tissue for analysis, and are not influenced by environmental conditions (Weeden and Wendel, 1989). Vaillancourt *et al.* (1992) and Githiri (1995) studied isozyme polymorphism in cowpea and observed that aspartate amino transferase (AAT) was polymorphic among cowpea cultivars. The present study was undertaken to test for linkage between the aphid resistance genes, *Rac*1 and *Rac*2, and genes controlling various morphological traits and the aspartate amino transferase (AAT) isozyme in cowpea. Isozyme variation at the AAT locus was studied using horizontal starch gel electrophoresis of the parents and F2-derived F3 progenies of the cross ICV 12 x Tvu 946. This cross was selected because, when staining for the isozyme AAT in the parent cultivars, it was observed that cultivar Tvu 946 had a none allele while cultivar ICV 12 stained for one band (Githiri, 1995). Techniques for isozyme analyses were adapted from (Weeden and Wendel, 1989). Cowpea seeds soaked on wet filter paper for 24-30 hr at room temperature were used for enzyme extraction. The extract was absorbed onto sewing thread wicks and inserted in the appropriate slits of starch gel (8 per cent gels made with hydrolysed starch from Sigma Chemical Co.). After loading the samples, the gel was mounted onto the electrode trays containing lithium-borate electrode buffer (Weeden and Wendel, 1989) and connected to a LKB continous-current power supply. Electrophoresis was conducted at constant current (250 mA, 38 W) for about 3 hr at 4^{0} C. Aspartate amino transferase (AAT) activity was revealed by immersing the gel slices in a stain assay composed of 20 mg L-aspartic acid, 10 mg -ketoglutaric acid, 15 mg fast blue BB salt, 0.2 mg pyridoxal-5'-phosphate and 15 ml lithium-borate electrode buffer, pH 8.1, for about one hour at room temperature. The zymograms were scored as present or absent. Results of inheritance of some selected morphological traits, AAT isozyme and aphid resistance from four crosses indicated that all these traits were simply inherited

(monogenic) and they segregated either in a 3:1 or 1:2:1 ratio. Results of pooled populations from different crosses, where applicable, also gave good fits for monogenic inheritance.

2.7.4 Cytology

Lavania and Lavania (1981) reported, by using the Giemsa C-banding technique, chromosome banding patterns on the somatic chromosomes of eight important pulse crops, *Pisum sativum* L. (garden pea), *Lens culinaris* Medik (lentil), *Cyamopsis tetragonoloba* L. Taub. (guar), *Cicer arietinum* L. (chick pea), *Cajanus cajan* L. Millsp. (pigeon pea), *Vigna radiata* L. Wilczek (mung bean), *Vigna mungo* L. Hepper (urd), *Vigna unguiculata* L. (Walp) (cowpea). Each species has a characteristic C-banding pattern. The significance of such banding patterns which correlate with the position of pachytene knobs, in chromosome identification, and in assigning relationships at the cytological level in the pulses of genus *Vigna* is stressed.

CHAPTER 3

MATERIALS AND METHODS

This chapter explains the plant material used, design of experiment, observation recorded. In the later part of this chapter methods are described using which various morphological, biochemical and cytological tests were conducted.

3.1 Materials

Genotypes of cowpea *Vigna unguiculata* including three cultigroups i.e. *unguiculata, catjang, sesquipedalis*, procured from local and indigenous regions were used for the present work. They have characteristics for erect, semi erect and compact and spreading growth habit, early flowering and early maturity, pest, disease tolerance, drought and heat tolerance which need to be incorporated for improvement of fodder cowpea. Seven of them were procured from northeastern region of the country and possessed the characteristics of early maturity and are mainly meant for seed. Altogether 168 indigenous and exotic cowpea genotypes and 4 checks were employed in the experiment during 2004-05 and 2005-06. The checks were Bundel lobia-1, Bundel lobia-2, UPC-5286 and local control IGFRI-95-1. These 168 germplasm lines along with checks and control are shown in Table 3.1.

3.2 Methods

Experimentations with 168 genotypes, 3 checks and 1 control of cowpea were done at farm of Crop Improvement Division of Indian Grassland and Fodder Research Institute, Jhansi during the years 2004-05 and 2005-06. One hundred sixty eight genotypes, 3 checks and 1 control of cowpea were sown on 18^{th} July, 2004 and 25^{th} July 2005 in augmented block design. Augmented block design is preferable to grow and evaluate the germplasm when collections are large (Federer, 1956). The layout consisted of 7 strips with 24 germplasm lines, 3 checks and 1 control in each strip. There were two rows of each germplasm with a spacing of 60 cm from row to row and 100 cm from entry to entry. The plant to plant spacing was kept as 15 cm. Plates 3.1 and 3.2 show the field experiments.

Table 3.1 *Vigna unguiculata* germplasm evaluated during 2004-05 and 2005-06

Sl. No.	Accession	Cultigroup	Source	
1	Hy10-36-4	*unguiculata*	Indigenous	IGFRI Jhansi
2	EC-48720	*unguiculata*	Exotic	NBPGR New Delhi
3	IVM-1	*unguiculata*	Indigenous	IGFRI Jhansi
4	EC-244310	*unguiculata*	Exotic	NBPGR New Delhi
5	EC-240564	*unguiculata*	Exotic	NBPGR New Delhi
6	EC-244979	*unguiculata*	Exotic	NBPGR New Delhi
7	EC-240887	*unguiculata*	Exotic	NBPGR New Delhi
8	HY10P52-7	*unguiculata*	Indigenous	IGFRI Jhansi
9	HY6P52-3	*unguiculata*	Indigenous	IGFRI Jhansi
10	EC-240884	*unguiculata*	Exotic	NBPGR New Delhi
11	EC-244236	*unguiculata*	Exotic	NBPGR New Delhi
12	NP-3-14-A	*unguiculata*	Indigenous	IGFRI Jhansi
13	HY6P52-10	*unguiculata*	Indigenous	IGFRI Jhansi
14	HY6P52-9	*unguiculata*	Indigenous	IGFRI Jhansi
15	HY10P58-3	*unguiculata*	Indigenous	IGFRI Jhansi
16	EC120001	*unguiculata*	Exotic	NBPGR New Delhi
17	EC241023	*unguiculata*	Exotic	NBPGR New Delhi
18	EC244223-1	*unguiculata*	Exotic	NBPGR New Delhi
19	NP-3-7	*unguiculata*	Indigenous	IGFRI Jhansi
20	EC-240714	*unguiculata*	Exotic	NBPGR New Delhi
21	EC-244243	*unguiculata*	Exotic	NBPGR New Delhi
22	EC-240840	*unguiculata*	Exotic	NBPGR New Delhi
23	NP-3-10	*unguiculata*	Indigenous	IGFRI Jhansi
24	EC-244249	*unguiculata*	Exotic	NBPGR New Delhi
25	HY-5P-6S-215	*unguiculata*	Indigenous	IGFRI Jhansi
26	EC-244217	*unguiculata*	Exotic	NBPGR New Delhi
27	IVM	*unguiculata*	Indigenous	IGFRI Jhansi
28	EC-240998	*unguiculata*	Exotic	NBPGR New Delhi
29	EC-240650	*unguiculata*	Exotic	NBPGR New Delhi
30	RA-2	*unguiculata*	Indigenous	IGFRI Jhansi
31	EC-240999	*unguiculata*	Exotic	NBPGR New Delhi
32	UPC-870	*unguiculata*	Indigenous	IGFRI Jhansi
33	HY-10-P-10-2-4	*unguiculata*	Indigenous	IGFRI Jhansi
34	RAJL-4	*unguiculata*	Indigenous	ICAR Research Complex Barapani
35	NP-3-8	*unguiculata*	Indigenous	IGFRI Jhansi
36	EC-240800	*unguiculata*	Exotic	NBPGR New Delhi
37	EC-240740	*unguiculata*	Exotic	NBPGR New Delhi
38	EC-244217-1	*unguiculata*	Exotic	NBPGR New Delhi
39	NP-3-14-B	*unguiculata*	Indigenous	IGFRI Jhansi
40	EC240842	*unguiculata*	Exotic	NBPGR New Delhi
41	Local-3	*sesquipedalis*	Indigenous	ICAR Research Complex Barapani
42	Local-2	*sesquipedalis*	Indigenous	ICAR Research Complex Barapani
43	Local-1	*sesquipedalis*	Indigenous	ICAR Research Complex Barapani
44	NP-3-7-1	*unguiculata*	Indigenous	ICAR Research Complex Barapani
45	HY-5p-32-2b	*unguiculata*	Indigenous	IGFRI Jhansi
46	EC-24077	*unguiculata*	Exotic	NBPGR New Delhi
47	NP-652-Y	*unguiculata*	Indigenous	IGFRI Jhansi
48	IL-99-69	*unguiculata*	Indigenous	IGFRI Jhansi
49	EC-241037	*unguiculata*	Exotic	NBPGR New Delhi
50	EC240898	*unguiculata*	Exotic	NBPGR New Delhi
51	HY-6P-05-28	*unguiculata*	Indigenous	IGFRI Jhansi
52	EC-240782	*unguiculata*	Exotic	NBPGR New Delhi
53	IL-181	*unguiculata*	Indigenous	IGFRI Jhansi
54	IL-792	*unguiculata*	Indigenous	IGFRI Jhansi
55	IL-179	*unguiculata*	Indigenous	IGFRI Jhansi
56	IL-90	*unguiculata*	Indigenous	IGFRI Jhansi
57	IL-178-8	*unguiculata*	Indigenous	IGFRI Jhansi
58	EC-240809	*unguiculata*	Exotic	NBPGR New Delhi
59	IL-55-1	*unguiculata*	Indigenous	IGFRI Jhansi
60	IL-177	*unguiculata*	Indigenous	IGFRI Jhansi

Table 3.1 Cont...

Sl. No.	Accession	Cultigroup	Source	
61	RAJ-2	*catjang*	Indigenous	ICAR Research Complex Barapani
62	IL-99-40	*unguiculata*	Indigenous	IGFRI Jhansi
63	IL-99-38	*unguiculata*	Indigenous	IGFRI Jhansi
64	IL-99-34	*unguiculata*	Indigenous	IGFRI Jhansi
65	IL-99-98-1	*unguiculata*	Indigenous	IGFRI Jhansi
66	IL-99-98	*unguiculata*	Indigenous	IGFRI Jhansi
67	IL-99-73	*unguiculata*	Indigenous	IGFRI Jhansi
68	IL-99-2	*unguiculata*	Indigenous	IGFRI Jhansi
69	IL-99-72	*unguiculata*	Indigenous	IGFRI Jhansi
70	IL-99-65	*unguiculata*	Indigenous	IGFRI Jhansi
71	IL-01-88	*unguiculata*	Indigenous	IGFRI Jhansi
72	IL-99-171	*unguiculata*	Indigenous	IGFRI Jhansi
73	IL-3117	*unguiculata*	Indigenous	IGFRI Jhansi
74	IL-15-1	*unguiculata*	Indigenous	IGFRI Jhansi
75	IL-155-1	*unguiculata*	Indigenous	IGFRI Jhansi
76	IL-3168-A	*unguiculata*	Indigenous	IGFRI Jhansi
77	IL-160-B	*unguiculata*	Indigenous	IGFRI Jhansi
78	IL-886	*unguiculata*	Indigenous	IGFRI Jhansi
79	IL-132	*unguiculata*	Indigenous	IGFRI Jhansi
80	IL-160	*unguiculata*	Indigenous	IGFRI Jhansi
81	IL-1155-B	*unguiculata*	Indigenous	IGFRI Jhansi
82	IL-966	*unguiculata*	Indigenous	IGFRI Jhansi
83	IL-144A	*unguiculata*	Indigenous	IGFRI Jhansi
84	IL-3178	*unguiculata*	Indigenous	IGFRI Jhansi
85	IL-160-A	*unguiculata*	Indigenous	IGFRI Jhansi
86	HY-8-P-66	*unguiculata*	Indigenous	IGFRI Jhansi
87	IL-2000-180	*unguiculata*	Indigenous	IGFRI Jhansi
88	IL-2000-184	*unguiculata*	Indigenous	IGFRI Jhansi
89	IL-2000-182	*unguiculata*	Indigenous	IGFRI Jhansi
90	IL-2000-188	*unguiculata*	Indigenous	IGFRI Jhansi
91	IL-2000-187	*unguiculata*	Indigenous	IGFRI Jhansi
92	IL-2000-178	*unguiculata*	Indigenous	IGFRI Jhansi
93	IL-2000-179	*unguiculata*	Indigenous	IGFRI Jhansi
94	IL-2000-189	*unguiculata*	Indigenous	IGFRI Jhansi
95	IL-2000-183	*unguiculata*	Indigenous	IGFRI Jhansi
96	EC-244236A	*unguiculata*	Exotic	NBPGR New Delhi
97	IL-178-4	*unguiculata*	Indigenous	IGFRI Jhansi
98	IL-390	*unguiculata*	Indigenous	IGFRI Jhansi
99	IL-131	*unguiculata*	Indigenous	IGFRI Jhansi
100	IL-853	*unguiculata*	Indigenous	IGFRI Jhansi
101	IL-1053	*unguiculata*	Indigenous	IGFRI Jhansi
102	IL_246	*unguiculata*	Indigenous	IGFRI Jhansi
103	IL-3171	*unguiculata*	Indigenous	IGFRI Jhansi
104	IL-380	*unguiculata*	Indigenous	IGFRI Jhansi
105	IL-1057	*unguiculata*	Indigenous	IGFRI Jhansi
106	IL-160-9	*unguiculata*	Indigenous	IGFRI Jhansi
107	IL-622	*unguiculata*	Indigenous	IGFRI Jhansi
108	IL-210	*unguiculata*	Indigenous	IGFRI Jhansi
109	IL-3138-B	*unguiculata*	Indigenous	IGFRI Jhansi
110	IL-892	*unguiculata*	Indigenous	IGFRI Jhansi
111	IL-966-B	*unguiculata*	Indigenous	IGFRI Jhansi
112	IL-1014-1	*unguiculata*	Indigenous	IGFRI Jhansi
113	IL-416-4	*unguiculata*	Indigenous	IGFRI Jhansi
114	IL-921	*unguiculata*	Indigenous	IGFRI Jhansi
115	IL-380-A	*unguiculata*	Indigenous	IGFRI Jhansi
116	IL-372	*unguiculata*	Indigenous	IGFRI Jhansi
117	IL-419-1	*unguiculata*	Indigenous	IGFRI Jhansi
118	IL-362	*unguiculata*	Indigenous	IGFRI Jhansi
119	IL-812-1	*unguiculata*	Indigenous	IGFRI Jhansi
120	IL-1050-3	*unguiculata*	Indigenous	IGFRI Jhansi

Table 3.1 Cont...

Sl. No.	Accession	cultigroup	Source	
121	IL-1177	*unguiculata*	Indigenous	IGFRI Jhansi
122	IL-867	*unguiculata*	Indigenous	IGFRI Jhansi
123	IL-161-1	*unguiculata*	Indigenous	IGFRI Jhansi
124	IL_153-1	*unguiculata*	Indigenous	IGFRI Jhansi
125	IL-812	*unguiculata*	Indigenous	IGFRI Jhansi
126	IL-200	*unguiculata*	Indigenous	IGFRI Jhansi
127	IL-893	*unguiculata*	Indigenous	IGFRI Jhansi
128	IL-156	*unguiculata*	Indigenous	IGFRI Jhansi
129	IL-1182	*unguiculata*	Indigenous	IGFRI Jhansi
130	IL-4216	*unguiculata*	Indigenous	IGFRI Jhansi
131	IL-380B	*unguiculata*	Indigenous	IGFRI Jhansi
132	IL-1177-A	*unguiculata*	Indigenous	IGFRI Jhansi
133	IL-380-C	*unguiculata*	Indigenous	IGFRI Jhansi
134	IL-578-A	*unguiculata*	Indigenous	IGFRI Jhansi
135	IL-370	*unguiculata*	Indigenous	IGFRI Jhansi
136	IL-1170-A	*unguiculata*	Indigenous	IGFRI Jhansi
137	IL-1072-1-5	*unguiculata*	Indigenous	IGFRI Jhansi
138	IL-419-2	*unguiculata*	Indigenous	IGFRI Jhansi
139	IL-893-1	*unguiculata*	Indigenous	IGFRI Jhansi
140	IL-14177-A	*unguiculata*	Indigenous	IGFRI Jhansi
141	IL-1086-2	*unguiculata*	Indigenous	IGFRI Jhansi
142	IL-155	*unguiculata*	Indigenous	IGFRI Jhansi
143	IL-216-1	*unguiculata*	Indigenous	IGFRI Jhansi
144	IL-887	*unguiculata*	Indigenous	IGFRI Jhansi
145	IL-160-11·	*unguiculata*	Indigenous	IGFRI Jhansi
146	IL-1721	*unguiculata*	Indigenous	IGFRI Jhansi
147	IL-3152-1	*unguiculata*	Indigenous	IGFRI Jhansi
148	IL-3155	*unguiculata*	Indigenous	IGFRI Jhansi
149	IL-18720-A	*unguiculata*	Indigenous	IGFRI Jhansi
150	IL-3168-B	*unguiculata*	Indigenous	IGFRI Jhansi
151	IL-632	*unguiculata*	Indigenous	IGFRI Jhansi
152	IL-1156-1	*unguiculata*	Indigenous	IGFRI Jhansi
153	IL-1177-B	*unguiculata*	Indigenous	IGFRI Jhansi
154	EC-24102-1	*unguiculata*	Exotic	NBPGR New Delhi.
155	RAJL-2	*unguiculata*	Indigenous	ICAR Research Complex Barapani
156	IL-1063	*unguiculata*	Indigenous	IGFRI Jhansi
157	IL-182	*unguiculata*	Indigenous	IGFRI Jhansi
158	RAJL-16	*unguiculata*	Indigenous	ICAR Research Complex Barapani
159	IL-200-186	*unguiculata*	Indigenous	IGFRI Jhansi
160	IL-14	*unguiculata*	Indigenous	IGFRI Jhansi
161	IL-3192	*unguiculata*	Indigenous	IGFRI Jhansi
162	IL-3177	*unguiculata*	Indigenous	IGFRI Jhansi
163	IL-3157	*unguiculata*	Indigenous	IGFRI Jhansi
164	IL-160-C	*unguiculata*	Indigenous	IGFRI Jhansi
165	IL_892	*unguiculata*	Indigenous	IGFRI Jhansi
166	IL-449	*unguiculata*	Indigenous	IGFRI Jhansi
167	IL-1471	*unguiculata*	Indigenous	IGFRI Jhansi
168	IL-4170	*unguiculata*	Indigenous	IGFRI Jhansi
169	BL-1	*unguiculata*	Indigenous	IGFRI Jhansi (Check) cultivar
170	BL-2	*unguiculata*	Indigenous	IGFRI Jhansi (Check) cultivar
171	UPC-5286	*unguiculata*	Indigenous	IGFRI Jhansi (Check) cultivar
172	IGFRI-95-1	*unguiculata*	Indigenous	IGFRI Jhansi (Local control)

Plate 3.1 ***Vigna unguiculata*** **germplasm grown for evaluation during the year 2004-05**

Plate 3.2 ***Vigna unguiculata*** **germplasm grown for evaluation during the year 2005-06**

3.3 Observations

The observations were recorded according to minimal descriptor for Agri-horti crops (Anon. 2007 - NBPGR). The data was collected from 5 plants from each line at vegetative, reproductive and harvesting stage. These traits included following characters.

Vegetative traits

These included Early plant vigour, Plant growth habit, Plant height, Length of main shoot per branch, Number of nodes, Number of primary branches, Number of secondary branches, Number of leaves per plant, Leaf length, Leaf width, Leaf weight per plant, Stem weight per plant, Biomass per plant, fresh leaf/stem ratio, Dry leaf weight, Dry stem weight, Dry weight per plant and Dry leaf per stem ratio.

Reproductive traits

These included Days to flowering initiation, Days to 50 per cent flowering, Days to maturity initiation and Days to total maturity.

Seed and yield traits

These included Number of pod cluster/plant, Number of pods per plant, Pod length, Seeds per pod, 100 seed weight, Seed weight per plant and Number of seeds per plant.

Data analysis

The morphological data of twenty nine forage and yield traits was analyzed for years 2004-05, 2005-06 and pooled average of both years using SPAR -1 statistical package software. Study of genetic variability, correlation, path analysis of forage and grain yield, yield attributing characters were performed for selection. Clustering of 172 germplasm lines was done based on morphological attributes.

3.4 Biochemical tests

3.4.1 Ripe seed test

There are different methods used to distinguish varieties, hybrids their parental lines etc. from each other. The seeds may give some identical colour reaction to various chemicals according to variation in genetic constitution and chemical composition of seeds and seed coat of different cultivars. The chemical reactions are stable and reproducible and can be conducted in relatively short time. So, biochemical

characterization of thirty six germplasm lines was done following standard procedures. Table 3.2 shows the germplasm lines taken for biochemical tests. Plate 3.3 shows the seeds of 36 lines *Vigna unguiculata* germplasm used for biochemical characterization.

Six bio-chemical seed tests *viz.* peroxidase enzyme test, KOH bleach test, NaoH test (Chemlar and Mostovoj, 1938), GA3 growth response test (Payne, 1976), fluorescence test (Grabe, 1957) and modified phenol test (Csala, 1972) were performed for effective distinction of thirty six germplasm lines of cowpea given in Table 3.2. All the chemical tests of seed were conducted under uniform controlled conditions.

3.4.1.1 Peroxidase activity test

The Peroxidase activity in the seed coat is used as an indicative of varietal distinctness in soybean (Payne, 1976). The seed coats of 20 seeds were separated carefully so that no piece of cotyledons remained. To facilitate this procedure the seeds were placed in water for 2 hours. The seed coats were then placed in a tube and 3-4 ml of 0.5% guaiacol solution (stored in refrigerator) was added.

After 10 minutes, one drop of 0.1 % H_2O_2 solution was added with gentle swirling. The solution changed to dark red/ brown colour for a positive reaction, or remained without colour for a negative reaction. The recording of this reaction was done in less than 10 seconds after adding the H_2O_2 solution for better recording of the observation, the tubes were placed over a white surface and the colorations due to peroxidase activity were recorded as absent [1] and present [2].

Table 3.2 *Vigna unguiculata* germplasm lines for biochemical tests

No.	Accession	Origin	Cultigroup
1	EC 548999	Kenya	*unguiculata*
2	EC 548878	Taiwan	*sesquipedalis*
3	Hy 6p 52-10	India	*unguiculata*
4	EC 24102-1	India	*unguiculata*
5	EC 548875	Thailand	*sesquipedalis*
6	EC 244236	India	*unguiculata*
7	IL- 1063	India	*unguiculata*
8	EC 548851	Australia	*unguiculata*
9	IL-160-B	India	*unguiculata*
10	IL 3178	India	*unguiculata*
11	IL-390	India	*unguiculata*
12	RAJL-16	India	*unguiculata*
13	IC 438864	India	*cylindrical*
14	IC 438865	India	*sesquipedalis*
15	RAJ-2	India	*catjang*
16	IL-2000-184	India	*unguiculata*
17	NP-3-14-A	India	*unguiculata*
18	IL-1177	India	*unguiculata*
19	EC 240884	India	*unguiculata*
20	IL-99-34	India	*unguiculata*
21	EC 548850	Australia	*unguiculata*
22	EC 240564	India	*unguiculata*
23	EC 548861	Guatemala	*cylindrical*
24	NP-3-14-B	India	*unguiculata*
25	IL-156	India	*unguiculata*
26	RAJL-2	India	*unguiculata*
27	IL-99-72	India	*unguiculata*
28	IL-1170-A	India	*unguiculata*
29	IVM-1	India	*unguiculata*
30	IL-3152-1	India	*unguiculata*
31	EC 548864	Tanzania	*pubescence*
32	EC 548865	Tanzania	*pubescence*
33	IL-131	India	*unguiculata*
34	EC 548873	China	*sesquipedalis*
35	EC 548866	Nepal	*sesquipedalis*
36	EC 548867	China	*sesquipedalis*

3.4.1.2 GA_3 response test

The seeds were surface sterilized with 0.1% sodium hypochlorite (AR grade) solution and then washed with distilled water. The sterilized seeds were germinated using standard BP (between paper towel) method as per ISTA rules. The paper towel presoaked with freshly prepared 100 ppm GA3 was used to study the growth response of seedlings. The water treated paper towels were used as the control. The seedling length and the dry

Vigna unguiculata cv.gr. *pubescence*, EC 548864

Vigna unguiculata cv.gr. *sesquipedalis*, EC 548878, EC 548875

Vigna unguiculata cv.gr. *cylindrical*, IC 438864

Plate 3.3 *Vigna unguiculata* lines used for biochemical characterization

weight were recorded at the final count i.e. 8th day. The lines with 20-30 % increase in growth over water treated control were grouped as high responsive lines where others were grouped as low responsive lines.

3.4.1.3 Fluorescence test (Grabbe, 1957)

Following Grabbe (1957), the seeds were surface sterilized with 0.5% solution of sodium hypochlorite and then washed with distilled water. The sterilized seeds were germinated using standard BP (between paper towel) method as per ISTA rules. Five to ten days old seedlings were removed and arranged on a moist filter paper at a reasonable distance so as to avoid the over lapping of seedlings. The seedlings were then examined for fluorescence of hypocotyls and root using Tran's illuminator. The lines showing fluorescence were grouped as positive and showing no fluorescence were grouped as negative.

3.4.1.4 Sodium hydroxide test (Chemelar and Mostovoj 1938)

Seeds were washed with distilled water and then soaked in 5% sodium hydroxide (AR grade) solution for 30 minutes. After the treatment the seeds were washed again with distilled water and observed the change in colour of seed coat. The lines with reddish brown colour of seed coat were grouped as positive response, whereas without change in colour were grouped as negative response.

3.4.1.5 KOH Bleach test

The presence or absence of darkly pigmented testa or undercoat layer is being used to differentiate Sorghum cultivars. The dark pigment in the testa can be identified as tannic acid. However, cowpea seeds show variation in seed coat colour but still the following seed test was performed in thirty six germplasm lines. To conduct the test a 1:5 (wt/vol) solution of potassium hydroxide and fresh household bleach (5.25% NaOCl) was prepared. The solution was stored in refrigerator. The seeds were soaked for 10 minutes in KOH Bleach solution. The mixture was stirred gently periodically. Then the seeds were rinsed with tap water and dried on paper towel. The lines were observed for following colour reaction groups, Black or no colour.

3.4.1.6 Phenol Colour test (Csala, 1972)

Fifty seeds of each line in four replications were soaked in water for 16 h at 20 ± 1^0C temperature. The soaked seeds were placed in Petri dishes lined with filter paper

soaked with 1% phenol solution. The Petri dishes were kept under laboratory conditions at 30 ± 1^{0}C. The final reaction was observed after 5-6 h and genotypes were classified into following colour reaction groups, Black coat, Black tip, Black colour.

3.4.2 Isozyme analysis

The Isozyme analysis of thirty six germplasm lines (Table 3.2) was performed on poly acrylamide gel for Esterase, Peroxidase, Polyphenyl peroxidase and SDS PAGE as per standard procedures (Markert, 1959).

Chemicals used in Isozyme analysis

Acryalamide, Bis acralamide, mercaptoethanol, N,N,N,N-tetramethyl ethylene diamine and brilliant blue R250 were obtained from SRL India, tris-buffer, ethanol, ethylene diamine tetra acetic acid (EDTA), P-phenylenediamine, cathecol, alpha napthlene acetate, riboflavin, APS, agar, $MgCl_2$, brilliant blue G250, tween-80 NaCl were obtained from High Media, Glycine and sucrose were obtained from Bio-Rad, methanol, acetic acid, Trichloro acetic acid sodium dihydrogen phospate, H_2O_2, Di sodium hydrogen phosphate, sodium hydroxide were obtained from Qualigens fine chemicals of India, Fast Blue RR salt was obtained from Sigma USA. Using these chemicals following tests were carried out.

3.4.2.1 Preparation of enzyme extract for isozyme and SDS page

The fresh and young seedlings were used to carry out the biochemical analysis. One to two gram fresh young seedlings were ground in 1ml of native phosphate buffer after centrifugation at 12000 rev/min for 20 minutes after which it was stored at 4° C and used as protein source.

3.4.2.2 Poly Acrylamide Gel Electrophoresis (PAGE)

Polyacrylamide gel was prepared by polymerzing acrylamide (CH_2=CH-$CONH_2$) with a small quantity of cross-linking reagent methylene bis acrylamide in the presence of a catalyst ammonium per sulphate. Tetramethylene diamine (TEMED) was also present to initiate and control the polymerization.

Thoroughly clean and dry glass plates were assembled properly and were clamped firmly in the upright position with the casting apparatus. 2% agar (melted in boiling water bath) was then applied around the spacers to hold them in place and sealed the chamber

between the glass plates. Preparation of 40 ml resolving gel mixture was done by mixing [(16 ml of stock acrylamide solution for 12%gel + 10 ml of Tris Cl (1.9M PH adjusted to 8.8) + 14 ml of Water + 20 µl of TEMED + 200 µl of APS (10%)].

After mixing the solution carefully, gel solution was poured in the chamber between the glass plates. After some time 200-400 µl butanol was added on the top of the gel and left for 20-30 min for polymerization.

After that preparation of 10 ml stacking gel mixture was done by mixing [(1.7 ml of stock acrylamide solution for 5% gel + 1.3 ml of Tris Cl (0.6 M PH adjusted to 6.8) + 6.5 ml of Water + 6.5 ml of TEMED + 50 ml of APS (10%)]. Before pouring this on already polymerized resolving gel, butanol was completely drained off and washed thoroughly with water. Comb was properly placed in the stacking gel mixture and allowed to get polymerize for 25-30 minutes. Comb was removed after stacking gel was polymerized without disturbing the shape of the wells. The gel was carefully installed in the electrophoresis apparatus after removing the clamps and agar. Apparatus was filled with the electrode buffer and any trapped air bubbles at the bottom of the gel was removed. Cathode and anode point were connected and DC power was turned on. The gel was turned at a constant 150 V till it passed the stacking and after that it DC power was increased to 200 V for quicker separation. Native PAGE was performed at room temperature whereas the isozyme analysis was run inside the refrigerator to avoid the heating and denaturizing of the enzymes.

Samples were loaded with the help of the auto pipette (presence of Bromophenol blue in the sample buffer facilitated easy loading of samples). After the run was complete, gel was carefully removed from between the plates. A cut was made from where the samples were loaded first. The gel was now immersed in staining solution and left overnight for identification of bands. The protein absorbed the brilliant blue dye. Then the gel was transferred to suitable container with 300 ml de-staining solution and the dye that did not bind to protein was thus removed. The de-staining solution was changed frequently, particularly during initial periods, till the background of gel turned colorless. The gel was photographed.

3.4.2.3 Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis (SDS PAGE)

Sodium Dodecyl Sulphate is an anionic detergent, which binds strongly to, and denatures proteins. The number of SDS molecules bound to a polypeptide chain is approximately half the number of the amino acid residues in that chain. The protein- SDS complex carries net negative charges, hence move towards the anode and separation is

based on the size of protein. The procedures of gel preparation and casting were same as mentioned in native gel electrophoresis except that in the gel solution SDS was added in both resolving and stacking gel. Similarly in samples SDS loading dye was added in 1:1 ratio. The mixture was heated in water bath for 2-3 minutes and kept on ice till it was loaded. The gel was run as the native gel. Gel was removed and fixed in 10%TCA for 2-3 hour and then stained as native gel. Table 3.3 shows the composition of SDS resolving gel buffer (12%) and Table 3.4 shows the composition of SDS stacking gel buffer (5%).

Table 3.3 Composition of SDS resolving gel buffer (12%)

No.	Gel constituent	Volume
1	Distilled Water	14.0 ml
2	Tris-buffer (PH8.9)	10.0 ml
3	Stock Acrylamide solution (30%)	16.0 ml
4	SDS (10%)	400 µl
5	TEMED	20 µl
6	APS (10%)	200 µl
7	Total	40 ml

Table 3.4 Composition of SDS stacking gel buffer (5%)

No.	Gel constituent	Volume
1	Distilled Water	6.5 ml
2	Tris-buffer (pH 8.9)	1.3 ml
3	Stock Acrylamide solution (30%)	1.7 ml
4	SDS (10%)	100 µl
5	TEMED	10 µl
6	APS (10%)	50 µl
7	Total	10 ml

Esterase Gel was immersed in 100 ml 0.5 M sodium phosphate buffer and incubated at room temperature for 30 minutes. Fifty mg of alpha napthyl acetate was dissolved in 1 ml of 60 % acetone in an appendorf tube. Fifty mg Fast Blue RR salt was dissolved in the same tube and poured in already incubated gel.. Then the gel was again incubated at 37° C for 20-30 minutes in dark. The reaction was stopped by adding the mixture of methanol, acetic acid, water and ethyl alcohol in the ratio of 10:2:10:1. The gel was photographed using Olympus Om 2000 camera.

3.4.2.4 Peroxidase staining

For peroxidase staining the gel was incubated in a solution containing 100 ml, 0.5 M Sodium acetate buffer, 100 mg benzidine (dissolved by boiling) at room temperature. In the same buffer 10 ml 3% hydrogen peroxide and 5 ml acetic acid was added. The bright blue coloured bands appeared when the band was stained sufficiently, arrested the reaction by immersing the gel in the large volume of 0.67 % sodium hydroxide solution and 7 % acetic acid solution for 10 minutes.

3.4.2.5 Polyphenol Oxidase (PPO)

When the Bromophenol blue dye touched the bottom of the gel it was removed and incubated for 30 minutes at room temperature in 100 ml 0.1 M potassium phosphate buffer (pH 7.0) containing 0.1% p-phenylene–diamine. When the incubation was over, cathecol was added to final concentration of 10 mM in the same buffer. Dark brown bands appeared that were photographed using Plympus Om 2000 camera.

3.4.2.6 Nomenclature of Bands

The bands were scored from the point of origin where samples were loaded to the end of front/ dye movement. The slowest band was considered as band no. 1 and subsequently bands were numbered. The Rm values of the bands were calculated by the following formula.

Rm value = Distance traveled by the band / Distance traveled by the dye front

3.5 Cytological Study

Cytological study of pollen mother cells was conducted using rapid squash technique (Dyer, 1963).

3.5.1 Rapid squash method

The flower buds containing pollen mother cells were collected from field in the morning time between 6.45 a.m. and 7.30 am during 50% flowering. The best time for fixing was around 7.00 am to 7.30 am. The buds were dipped in Carnoy's fixative solution having 3:1 ratio of absolute ethyl alcohol: acetic acid for carrying them to laboratory. The anthers from appropriate size of buds were smeared in Lacto propionic orcein and visualized in photographic compound microscope.

Lacto propionic orcein used in rapid squash methods for chromosome preparations was prepared as follows: two gram of natural orcein was dissolved in 100

cm^3 of a mixture of equal parts of lactic and propionic acids and diluted to 45% with water. This stain was found very effective for fresh pollen mother cell preparations.

The following procedure was adopted for carrying out cytological study.

1. The fixed flower buds were taken from an inflorescence, starting from the smallest and going up to the largest, till the correct bud having divisional stages was found.
2. A single anther from a bud was dissected out with a needle and it was placed on a clean slide.
3. The entire anther on the slide was smeared with a scalpel, and a drop of Lacto propionic orcein was added to it immediately. Debris was removed.
4. It was heated slightly over a flame and covered with a cover glass to seal the solution and visualized in photographic compound microscope.

The metaphase plate, anaphase and diakinesis stages were observed in four accessions of three *V. unguiculata* cv. gr. i.e. *unguiculata* (2 accessions; IL-1177 and EC548999), *sesquipedalis* (1 accession; EC548875) and *cylindrical* (1 accession: IC 438864).

3.5.2 Pollen fertility

Fresh pollens of thirty six cowpea germplasm lines (Table 3.2) were dusted on glass slide and visualized in a drop of aceto-glycero carmine. The number of fertile and sterile pollens were counted for twenty five microscopic views and the average ratio was calculated which was converted to percent pollen fertility.

3.6 Weather data of the years 2004-05 and 2005-06

In 2004 the onset of monsoon was early arriving in the 24th standard meteorological week (June 11-17) and remained effective up to 37th standard meteorological week (September 10-16). The monsoon condition prevailed for nearly one month (June 18-July 15). The peak maximum temperature of 45.5 ^{0}C was on 31st May 2004 and peak minimum temperature of 2.1 ^{0}C was on 27th December 2004. In 2005 the onset of monsoon was delayed by one week and the rainfall received during July 2-8 was 84.4 mm. The total rainfall during Kharif season was 383.9 mm in 27 rainy days; 2005 has been characterized as the most disastrous drought year in last 66 years. It was interesting to note that the year 2005 was not hot year as compared to 2004 , the reason could be attributed to cloud cover without any rainfall during daytime. The minimum temperature was also higher than 2004.

CHAPTER 4

RESULTS

In this chapter, results obtained from field and laboratory experiments are presented. Analysis of collected data was carried out and interpretations were made. These are presented under following heads.

(a) Variability
(b) Frequency distribution
(c) Clustering pattern based on 1st year data
(d) Clustering pattern based on 2nd year data
(e) Cytology
(f) Biochemical Characterization

4.1 Variability

A wide range of variation was observed for the various characters recorded. These are discussed below.

4.1.1 Early plant vigour

Early plant vigour was observed after 25 days of sowing. Visual group observation was recorded considering seedlings of 20 cm and above height as very good, 15 cm to 20 cm height as medium and less than 15cm height as poor. The early vigour was recorded in both years i.e. 2004 and 2005 and it was noticed that out of 172 genotypes, 16 showed poor seedling vigour, 46 showed very good vigour while 110 showed medium seedling vigour. Genotypes EC-240884, NP-3-14-A and IL-182 showed very good early seedling vigour, lines IL-390, IL3117 and HY-10-36-4 showed poor early seedling vigour. Genotypes IL-1177, IL-887 and IL-3168-B showed medium early seedling vigour.

4.1.2 Plant growth habit

Plant growth habit was recorded at the completion of vegetative stage. Twelve genotypes were erect type, 53 genotypes were semi erect, six genotypes were bushy, 27 genotypes were ainy and 74 genotypes were spreading.

4.1.3 Days to 50 per cent flowering

Recorded as the number of days from sowing i.e. 18th July 2004 to the day when 50% of the plants in a row flowered. In 2004, days to 50% flowering ranged from 38 to 88 days. The early flowering types, 34 in number, flowered in 38-44 days. Six genotypes were late which flowered in 84-88 days. The earliest flowering accessions were EC-240564 and EC-244979 in 38 days and most late flowering genotype was IL-181 in 88 days i.e. by 16th October 2004. In 2005, date of sowing was 25th July 2005 and days to 50% flowering ranged from 39 to 87 days, the earliest flowering accession was EC-244217-1 in 39 days and most late genotype was IL-4216 in 87 days.

4.1.4 Days to total flowering

In year 2004 the days to total flowering ranged from 45 to 108 days from the date of sowing. Genotype IVM showed least days to total flowering i.e. 45 days, by 3rd September 2004 and genotype IL-181 had maximum days to total flowering i.e. 108 days, by 6th November 2004.

In 2005 the days to total flowering ranged from 49 to 106 days from the date of sowing, genotype NP-3-7-1 showed least days to total flowering i.e. 49 days and genotype IL181 had maximum days to total flowering i.e.106 days.

4.1.5 Plant height

Measured from the ground to the tip of the plant at 50% flowering i.e. when the crop is ready for harvesting green fodder, ranged from 105.9 cm to 234.9 cm on the pooled average basis and the tallest genotypes were, HY-10P-10-2-4 (234.9 cm) followed by IL-99-171 (231.7 cm) and Local-1 (231.2 cm) and shortest were, IL-168 (105.9 cm), NP-3-10 (113.0 cm) and HY 10P- 52-7 (115.3 cm). On the individual year basis in 2004-05 crop ranged from 66.9 cm to 294.0 cm. The tallest genotypes were, Local-2 (294.0cm), NP 652-Y (289.3 cm) and IL-2000-178 (283.6 cm) and shortest, were EC-240714 (66.9 cm), Hy-8p -66 (98.5 cm) and EC-240887 (109.9 cm) in 2004. In 2005 crop height ranged from 62.7 cm to 262.8 cm and the tallest genotypes were, IL-160-9 (262.8 cm), EC-120001 (241.3 cm) and IL-99-72 (237.3 cm) and shortest were, IL-390 (62.7 cm), IL-892 (84.9 cm) and EC 240740(95.5 cm).

4.1.6 Length of main branch

On the pooled average basis the maximum length (243.3 cm) of main branch was of genotype IL-1053, 219.36 and 203.11 cm of genotypes IL-892A and IL-99-69 respectively. However, shortest length (71.32 cm) of main branch was of accession EC-240884, followed by 75.10 and 80.03 cm for accessions IL-160-9 and IL-99-73 respectively. In the year 2004, the lengthiest main branches were 269.7, 248.4 and 238.6 cm of genotypes IL-892, IL-1053 and EC-24077 respectively and shortest main branches were 62.3, 77.3 and 84.5 cm for genotypes IL-3168-A, EC 240884 and IL-1086-2 respectively. In the year 2005, longer main branches were 238.3, 229.5 and 201.4 cm for genotypes IL-1053, IL-390 and IL-99-69 respectively. However, shorter main branch lengths were 41.3, 45.6 and 47.4 cm for genotypes IL-886, IL-3117 and IL-160-9 respectively.

4.1.7 Number of nodes per plant

On averaging both year's data, genotype RAJL-16 had minimum (13) nodes/plant lead by genotypes IL-578-A and NP-3-14-A having 14 nodes each. In the higher range genotype IL-419-1 had 29 modes/plant followed by genotypes IL 3117 (29) and IL-1057 (28). On considering individual years, in 2004, higher nodes per plant were in genotypes [IL 4170 and IL-419-1 (33 each); IL-416-4 and IL-1050-3 (32 each); and EC –240564 (31)] and lower nodes per plant were in genotypes [EC-240714 (12); EC-240842 (13); and IL-1182 (14)]. However, in the year 2005 higher nodes per plant were in genotypes [IL3117 and IL-1057 (33 each); IL-90, IL-178-4 and EC-48720 (31 each); and IL-99-73 (30)] and lower nodes per plant were in genotypes [IL-200-186 (10); RAJL-16 and IL-3177 (12 each); NP-3-14A, IL-578-A, IL-419-2 and RAJL-2 (13 each)].

4.1.8 Number of primary and secondary branches per plant

Pooled average data of the two years showed that genotypes having maximum number of primary branches were [IL-200 (10); IL-1057 (9); and IL-3178 and IL-160-A (8 each)] and genotypes having maximum number of secondary branches were [EC-244310, EC240564 and IL-1177 (13 each); and IL-155 (12)]. However, genotypes with minimum number of primary branches were [IL-99-38 and EC-240842 (3 each); and IL-99-38 (2)] and genotypes with minimum number of secondary branches were [IL-155-1 and IL-210 (1 each); and NP-3-7-1 (2)].

In the year 2005 genotypes having maximum number of primary branches were [IL-55-1 (12); IL-200 (11); and IL-1057 (9)] and genotypes having maximum number of

secondary branches were [EC-244310 and EC-240564 (13 each); IL-55-1 (10); and IL-3171 (9)]. However, genotypes with minimum number of primary branches were [IL-3192 and IL-160-C (1 each); IL-812 and IL-1177-B (2 each); and EC-244310 and IL-155-1 (3 each)] and genotypes with minimum number of secondary branches were [RA-2, EC-244217-1 and NP-3-7-1 (1 each)].

Considering the data of the year 2004 genotypes having maximum number of primary branches were [IL-812, IL-131 and IL-3155 (10 each)] and genotypes having maximum number of secondary branches were [IL-155 (21); IL-1177 and IL-200 (19 each); and IL-812 (18)]. However, genotypes with minimum number of primary branches were [RAJL-14 and IL-99-40 (2 each); IL-99-38 and IL-99-65 (3 each); and EC-244249 (3)] and genotypes with minimum number of secondary branches were [IL-155-1, Local – 1, NP-652-7 and HY-10P527 (1 each)].

4.1.9 Stem girth

Average of both years revealed that thinner stem diameters in cm were of genotypes [Local-2 (0.7); RAJL-4 (0.76); and EC-240842 (0.81)] and thicker stem diameters were of genotypes [IL-1177 (1.89); IL-99-69 (1.72); and IL-200 (1.70)]. In the year 2005 thinner stem diameters in cm were of genotypes [RAJL-16, IL-3192 and IL-3177 (0.52); IL-99-38 (0.53); and RA-2 and Local-2 (0.54)] and thicker stem diameters were of genotypes [IL-200 (1.71), IL-372 and IL 1086-2 (1.60); and EC 240999 (1.51)]. The data of the year 2004 showed that thinner stem diameters in cm were of genotypes [IL-1182 (0.74); EC-240842 and RAJL-4 (0.76); and Local-2 (0.86)] and thicker stem diameters were of genotypes [IL-1177 (2.50); IL-99-69 (2.36); and EC-244243 and EC-120001 (2.10)].

4.1.10 Leaves per plant

On averaging data of both years, accessions having less number of leaves per plant were [EC-240842 (23); Local-2 (26); and IL-99-38 (31)] and accessions having more number of leaves per plant were [IL-1177 (201); IL-1057 (185); and IL-1050-3 (158)]. Considering the leaves per plant in the year 2005, less leafy genotypes were [IL-3177 and NP-3-14-A (11); and EC-240998 (12)] and more leafy genotypes were [IL-55-1 (145); IL-792 (104); and IL-372 (102)]. However, in the year 2004 less leafy genotypes were [Local-2 (27); EC-240842 (32); and IL-99-72 and IL-55-1 (34 each)] and more leafy genotypes were [IL-1177 (372); IL-1057 (297); and IL-1050-3 (278)].

4.1.11 Leaf length

Taking the average of the two years 2005 and 2006, the accessions having higher leaf length in cm were [IL-372 (14.9); HY6P52-3 (14.7); and EC-120001 (14.5)] and the accessions having lower leaf length in cm were [EC-240999 (3.72); RA-2 (5.8); and EC-240842 (6.3)]. When taken separately for the year 2005, the accessions having higher leaf length in cm were [EC-244236 (16.7); IL-372 and HY6P-52-3 (16.5 each)] and the accessions having lower leaf length in cm were [EC-240999 (2.5); IL-99-98 (2.7); and IL-200-186 (2.8)]. For the year 2004, the accessions having higher leaf length in cm were [IL-892 (16.6); IL-99-171 (16.4); and IL-3192 (15.9)] and the accessions having lower leaf length in cm were [EC-240999 (4.9); IL-1050-3 (7.1); and IL-380 (7.3)].

4.1.12 Leaf width

Data pooled together for the year 2004 and 2005 showed that wider leaves with maximum width in cm were of genotypes [EC-244223-1 (11.0); IL-893 (10.8); and IL-3192 (10.6)] and narrower leaves with maximum width in cm were of genotypes [EC-240999 (2.5); IL-812 (3.77); and EC-240842 (3.9)]. In the year 2005 the leaf width in cm towards higher side were for the accessions [IL-893 (12.5); EC 244223 (11.3); and EC 48720 (10.1)] and leaf width in cm towards lower side were for the accessions [NP-3-14-A and EC-240999 (1.1); and IL-812 (1.4)]. However, in the year 2004 the leaf width in cm towards higher side were for the accessions [EC-240564 (12.9); IL-892 (12.6) and HY-10-36-4 (12.6)] and leaf width in cm towards lower side were for the accessions [IL-246 and IL-380 (5.1); EC-244236 A (5.0); and EC-240999 (3.8)].

4.1.13 Fresh biomass per plant

On pooling both year's data, the higher biomass in g were obtained for the accessions [IL-1177 (943.5); IL-3171 (775.1); and IL-966-B (663.7)] and lower biomass in g was obtained for accessions [EC-240842 (108.0); IL 99-38 (132.4); and (IL-99-40 (139.9)]. In the year 2005 higher biomass in g were obtained for the accessions [IL-1177 (781.61); IL—380-C (587.88) and IL -3171 (511.0)] and lower biomass in g was obtained for accessions [IL-99-38(98.69); IL-812(64.35) and IL-200-186 (117.69)]. However, in the year 2004 higher biomass in g were obtained for the accessions [IL-1177 (504.5); IL-155 (404.1); and HY-10-36-4 (335.7)] and lower biomass in g was obtained for accessions [EC-240842 (24.0); Local-2 (38.9); and IL-99-40 (50.9)].

4.1.14 Leaf / Stem ratio

On averaging two years' data it was found that higher leaf/stem ratios were for genotypes [HY6P52-3 (1.04); IL-893 (1.01); and IL-99-171 (0.95)] and lower leaf/stem ratios were for genotypes [IL-921 (0.19); EC-240999 (0.25); and NP-3-8 (0.26)]. In the year 2005 higher leaf/stem ratios were for genotypes [IL-99-171 (1.36); IL-893 (1.17); and IL-792 (1.13] and lower leaf/stem ratios were for genotypes [RA-2 (0.17); IL-921 (0.21); and EC-240999 (0.23)]. However, in the year 2004 higher leaf/stem ratios were for genotypes [IL-632 (1.09); HY-6P-52-3 (1.04); and EC-240887 (0.92)] and lower leaf/stem ratios were for genotypes [IL-921(0.17); NP-3-8 (0.27); and Local-2 (0.28)].

4.1.15 Dry weight per plant

On pooled average basis higher dry weight/ plant in g was obtained for the accessions [IL-1177 (625.51); IL-3171 (543.63); and IL-449 (345.94)] and lower dry weight/ plant were obtained for the accessions [EC-240842 (64.37); RAJ-2 (80.67); and IL-99-38 (77.05)]. In the year 2005, higher dry weight/ plant in g was obtained for the accessions [IL-1177 (541.8); IL-380-C (418.9); and HY6P-52-3 (272.6)] and lower dry weight/ plant were obtained for the accessions [IL-2000-183 (48.5); IL-853 (51.1); and EC-240898 (51.7)]. However, in the year 2004 higher dry weight/ plant in g was obtained for the accessions [IL-1177 (1105.5); IL-3171 (1038.9); and IL-155 (925.0)] and lower dry weight/ plant were obtained for the accessions [EC-240842 (97.6); RAJL-4 (147.1); and IL-99-98 (149.7)].

4.1.16 Dry Leaf / Stem ratio

On averaging both years data, accessions that showed higher dry Leaf/Stem ratio were [IL-160-A (1.02); IL-99-98-1 (0.97); and (IL-792 (0.94)] and accessions that showed lower dry Leaf/Stem ratio were [EC 240999 (0.21); NP 3-8 (0.24); and IL-1155-B (0.23)]. On taking the data separately for the year 2005, accessions that showed higher dry Leaf/Stem ratio were [IL-160-A (1.32); IL-372 (1.26); and IL-210 (1.16)] and accessions that showed lower dry Leaf/Stem ratio were [IL-99-98 (0.15); IL-3178 (0.17); and RA-2 (0.20)]. However for the year 2004, accessions that showed higher dry Leaf/Stem ratio were [IL-161-1 (1.34); IL-99-98-1 (1.23); and IL-3152-1 (1.05)] and accessions that showed lower dry Leaf/Stem ratio were [EC-240999 (0.19); IL-1155-B (0.21); and EC-240842 (0.22)].

4.1.17 100 seed weight

On averaging both years data genotypes that had higher 100 seed weight in g were [IL-181 (25.2); IL-4216 (22.6); and IL-156 (22.5)] and genotypes that had lower 100 seed weight in g were [RAJL-16 (6.9); IL-3155 (7.2); and EC-244310 (7.64)]. Taking year wise, in the year 2005 genotypes that had higher 100 seed weight in g were [IL-181 (25.7); IL-4216 (24.1); and IL-156 (23.9)] and genotypes that had lower 100 seed weight in g were [RAJL-16 (6.5); IL-3155 (7.1); and IL-3152-1 (7.9)]. However, in the year 2004 genotypes that had higher 100 seed weight in g were [IL-1053 (121.0); IL-390 (119.0); and IL-1721 and IL-370 (118.0)] and genotypes that had lower 100 seed weight in g were [IL-181 (24.8); HY-10P-10-2-4 (21.3); and IL-156 and IL-4216 (21.0)].

4.1.18 Days to maturity initiation

In year 2004, genotypes that showed early maturity initiation in days after sowing were [NP 3-10 (59); EC-240887 (60); and EC 240782 (61)] and genotypes that showed late maturity initiation were [IL-1053 (121); IL-390 (119); and IL-1721 and IL-370 (118)]. However, in the year 2005, genotypes that showed early maturity initiation in days after sowing were [NP-3-10 (61); EC-240887 (64); and HY-5p-65-215 (68)] and genotypes that showed late maturity initiation were [IL-416-4 (131); IL-1014-1 (130); and IL-853 (129)]. When the data of both years i.e. 2004 and 2005 was pooled together, the genotypes that showed early maturity initiation in days after sowing were [NP-3-10 (60); EC-240782 (61); and EC-240887 (62)] and genotypes that showed late maturity initiation were [IL-390 (120); IL-853 (119); and IL-1155-B (118)].

4.1.19 Days to total maturity

In year 2004, genotypes that took lesser number of days for total maturity of pod were [EC 240884 (110); NP 3-10, EC 120001 and HY 6P52-103 (111); and EC 240840 (112)] and genotypes that took more number of days for total maturity of pod were [IL-390 and IL15-1 (160); and EC 240782 (150)]. However, in the year 2005, genotypes that took lesser number of days for total maturity of pod were [EC-244979 (105); EC 244310 and EC 240714 (112); and HY 10P-10-2-4 (113)] and genotypes that took more number of days for total maturity of pod were [EC 240998 (161); IL 160-B (160); and EC 240840 (158)]. When the data of both years 2004 and 2005 was pooled together, the genotypes that took lesser number of days for total maturity of pod were [EC-244979 and IL 99-72 (113); EC-240884 and IL 99-65 (115); and EC 244310 (116)] and genotypes that took

more number of days for total maturity of pod were [IL-892, IL 380-A and IL 622 (148); IL-853 (147); and EC 240998(146)].

4.1.20 Number of clusters per plant

On averaging the data of years 2004 and 2005, the genotypes that showed higher number of cluster per plant were [IL 155-1 (30.7); IL 3168-A (28.8); and EC24102-1 (25.8)] and genotypes that showed lower number of clusters per plant were [IL 886 and IL160-A (1.37) and IL 1177 (1.95); IL 3168-A (2.06)]. The growth pattern of genotypes in year 2005 showed that higher number of clusters per plant were in [IL 1551 (31.0); IL 3168-A (30.1); and IL 90 (29.9)] and lower number of clusters per plant were in [IL 886 and IL160-A (1.4); NP3-14-B (2.0) and EC 244243-1 (2.1)]. Similarly, in year2004, the genotypes that showed higher number of cluster per plant were [IL 155-1 (30.0); IL 3168-A (28.0); and IL 362 (24.0)] and genotypes that showed lower number of clusters per plant were [HY 6P52-9 (1.0); EC-48720(2.0); and IL892 (3.0)]

4.1.21 Number of pods per plant

On averaging the data of years 2004 and 2005, the genotypes that showed higher number of pods per plant were [IL 3168A (53.2); IL156 (51.3); and IL2000-180 (50.5)] and genotypes that showed lower number of pods per plant were [NP3-8 (3.5); EC241037 (3.5); and IL 892-A (2.9)]. The growth pattern of genotypes in year 2005 showed that higher numbers of pods per plant were in [IL90 (55.2); IL99-72 (51.6); and IL 2000-180 (49.0)] and lower numbers of pods per plant were in [NP 3-8 (5.3); EC 241037 (4.6); and IL 892A (3.6)]. Similarly, in year2004, the genotypes that showed higher number of pods per plant were [IL 3168-A (65.4); IL 155-1 (59.0); and IL156 (55.6)] and genotypes that showed lower number of pods per plant were [NP 3-8 (1.8); EC 241037 (2.3); and IL178-8 (3.1)]

4.1.22 Pod length

On averaging both years data genotypes that had higher pod length in cm were [Local 1 (24.6); IL 2000-182 (24.4); and NP 3-7 (21.8)] and genotypes that had lower pod length in cm were [IL 792 (8.6); and IL 886 and IL 155 (9.2)]. Taking year wise, in the year 2005 genotypes that had higher pod length in cm were [Local 1 (25.3); IL 2000-182 (25.0); and EC 240809 (22.1)] and genotypes that had lower pod length in cm were [IL 3168-A (8.4); IL 99-98 (8.9); and IL 792 (9.0)]. However, in the year 2004 genotypes that had higher pod length in cm were [Local 1 (24.0); IL 2000-182 (23.7); and NP 3-7 (22.1)]

and genotypes that had lower pod length in cm were [IL 792 (8.1); IL 2000-188 (8.6); and IL 160-B (8.7)].

4.1.23 Seeds per pod

On averaging the data of years 2004 and 2005, the genotypes that showed higher number of seeds per pod were [Local-2 (22.2); Local-1 (21.1); and IL 1057 (20.8)] and genotypes that showed lower number of seeds per pod were [IL 153-1 (4.8); IL 160-C (7.7); and IL 181 (8.0)]. The growth pattern of genotypes in year 2005 showed that higher numbers of seeds per pod were in [IL 2000-182 (22.5); Local-2 (22.0); and IL-1057 (21.7)] and lower numbers seeds per pod were in [IL153-1 (5.7); IL 2000-188 and IL 2000-179 (7.5)]. Similarly, in year2004, the genotypes that showed higher number of seeds per pod were [Local-2 (22.3); Local-1 (21.3); and IL 1156-1 (20.0)] and genotypes that showed lower number seeds per pod were [IL 153-1 (4.0); IL-181 (6.9); IL 160-C (7.1); and IL 2000-189 (7.7)]

4.1.24 Seeds per plant

On averaging the data of years 2004 and 2005, the genotypes that showed higher number of seeds per plant were [EC 24102-1 (730.9); IL 3117 (725.4); and IL1177-B (720.5)] and genotypes that showed lower number of seeds per plant were [IL 892A (31.9); NP 3-8 (39.5); and IL 812 (45.2)]. The growth pattern of genotypes in year 2005 showed that higher numbers of seeds per plant were in [IL 160-9 (744.8); EC-240809 (733.2); and IL 160-11 (732.2)] and lower numbers of seeds per plant were in [IL 892-A (41.7); IL 812 (58.4); and HY 10P527 (60.3)]. Similarly, in year 2004, the genotypes that showed higher number of seeds per plant were [EC 24102-1 (757.7); IL 1177-B (740.1); and IL 362 (738.0)] and genotypes that showed lower number of seeds per plant were [NP 3-8 (18.7); IL 892-B (22.1); IL 178-B (27.5)]

4.2 Frequency distribution

Total 29 traits, parameters recorded for evaluated germplasm were considered for their frequency distribution. Wide variation was observed amongst the germplasm lines for various morphological and metric traits. The frequency distribution pattern for the pooled data of the years 2004 and 2005, varied from almost symmetrical to asymmetrical types in different cases. In general the pattern of distribution was of unimodal type. Figs. 4.1 to 4.29 show the frequency distribution of different parameters.

4.2.1 Early plant vigour

The pattern of frequency distribution of germplasm lines was symmetrical and unimodal. The maximum number i.e. 110 germplasm lines were observed in medium group of early plant vigour i.e. at 25 days after sowing the plant height ranged from 15 cm to 20 cm. Sixteen lines were grouped in poor vigour group with plant height less than 15 cm. Forty six genotypes were grouped in very good plant vigour group with plant height more than 20 cm. Fig. 4.1 shows the frequency distribution of early plant vigour.

4.2.2 Plant growth habit

The pattern of frequency distribution (Fig. 4.2) showed two peaks. The maximum number of genotypes i.e. 74 was spreading type, 53 were semierect type, 27 were ainy, 12 were erect types while six were bushy genotypes.

4.2.3 Days to 50 per cent flowering

The frequency distribution was symmetrical and unimodal with maximum number of 64 genotypes with days to 50% flowering from the date of sowing between 46 and 55 days. 41 germplasm lines flowered 50% between 56 and 65 days. 34 genotypes flowered 50% before and at 45 days from the date of sowing (Fig. 4.3).

4.2.4 Days to total flowering

The pattern of frequency distribution of days to total flowering (Fig. 4.4) was symmetrical and unimodal with maximum number of 102 genotypes with days to total flower between 56 to 75 days. 47 lines had total flowering between 76 to 95 days. 20 genotypes fully flowered in 96 to 115 days. While three genotypes fully flowered in less than 55 days from the date of sowing.

4.2.5 Plant height

The pattern of frequency distribution of plant height (Fig. 4.5) was symmetrical and unimodal with maximum number of genotypes i.e. 72 in 136 to 165 cm plant height class, 40 germplasm lines had plant height between 166 to 195 cm , 36 genotypes had plant height between 106 to 135 cm. 21 genotypes had plant height between 195 to 225 cm, while three germplasm lines had plant height more than 225 cm.

4.2.6 Length of main branch

The pattern of frequency distribution of length of main branch (Fig. 4.6) was uinmodal, symmetrical with maximum number of genotypes i.e. 98 having length of main branch between 116 to 160 cm. 39 genotypes were having length of main branch between 161 and 205cm. 33 germplasm lines were having 71 to 115 cm long main branch. Two genotypes were found to have length of main branch in between 206- 250cm.

4.2.7 Number of nodes per plant

The pattern of frequency distribution was bimodal and flat topped. Seventy six genotypes were having nodes/plant from 21 to 25 while seventy four genotypes were found to have 16 to 20 nodes/plant. Eighteen genotypes were having 26 to 30 nodes/ plant. Fig. 4.7 shows the frequency distribution of number of nodes/plant.

4.2.8 Number of primary branches per plant

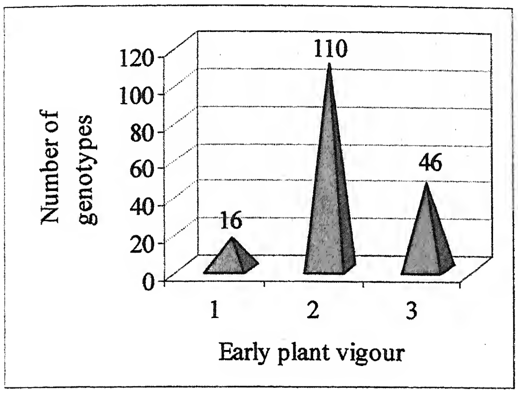
Frequency distribution pattern was unimodal and symmetrical with maximum number of 103 genotypes having five to six primary branches. Forty six genotypes were having seven to eight primary branches. Seventeen genotypes were found to have three to four primary branches. Four germplasm lines were having nine to ten primary branches. While single genotype was found to have less than two or two primary branches. Also there was a genotype with twelve or more than twelve primary branches. Fig. 4.8 shows the frequency distribution of number of primary branches/plant.

4.2.9 Number of secondary branches per plant

The pattern of frequency distribution of number of secondary branches/plant (Fig. 4.9) was descending and unimodal type. Maximum number of genotypes (101) had number of secondary branches equal to four or less than four. Fifty-seven genotypes were found to have five to eight secondary branches. Eleven genotypes were having nine to twelve secondary branches. Three genotypes were found to have thirteen to sixteen secondary branches.

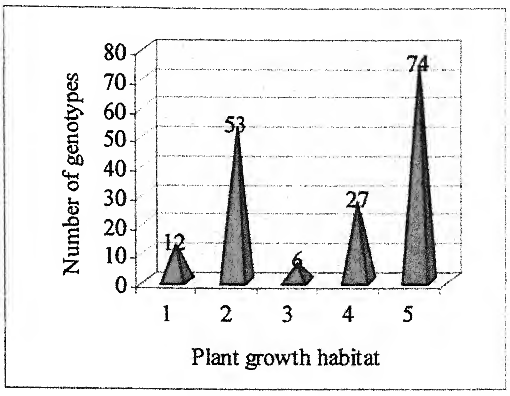
4.2.10 Stem girth

The pattern of frequency distribution of stem girth (Fig. 4.10) was unimodal and symmetrical with maximum number (92) of genotypes with stem girth 1.1 to 1.3 cm. Forty one genotypes had stem girth from 1.4 to 1.6 cm. Thirty five genotypes were found to have stem girth in the range of 0.8 to 1.0 cm. Three genotypes were in the class with stem girth ranged from 1.7 to 1.9. Single genotype was found to have stem girth equal to or less than 0.7 cm.



On X axis- 1: Poor (less than 15 cm); 2: Medium (15-20 cm); and 3: Good (more than 20 cm) seedling length after 25 DAS

Fig. 4.1 Frequency distribution of early plant vigour



On X axis- 1: Erect; 2: Semi-erect; 3: bushy; 4: ainy; and 5: spreading

Fig. 4.2 Frequency distribution of plant growth habit

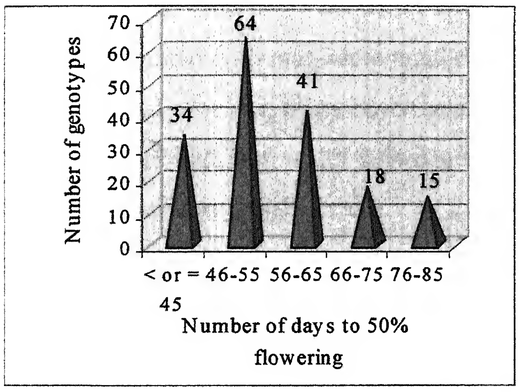


Fig. 4.3 Frequency distribution of days to 50 per cent flowering

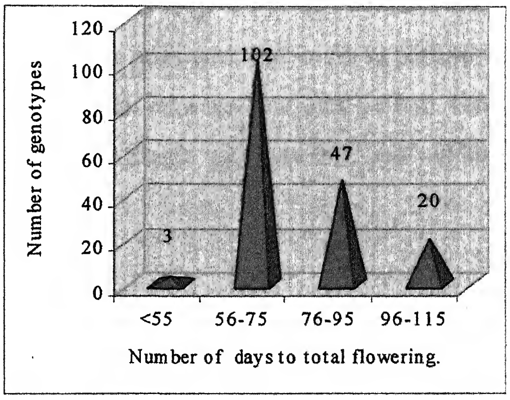


Fig. 4.4 Frequency distribution of days to total flowering

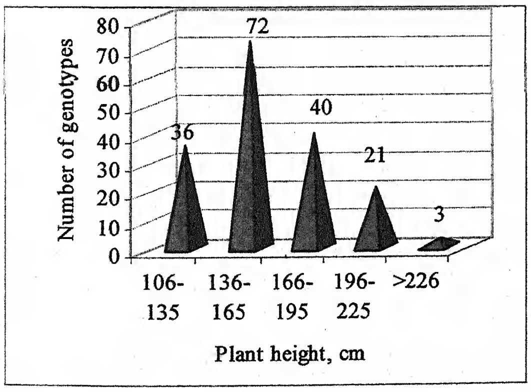


Fig. 4.5 Frequency distribution of plant height

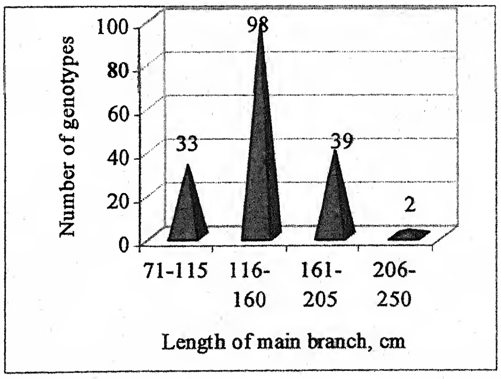


Fig. 4.6 Frequency distribution of length of main branch

4.2.11 Leaves per plant

The pattern of frequency distribution of leaves/plant (Fig. 4.11) was found to be unimodal descending type with maximum number (91) of genotypes with 21 to 70 leaves per plant. Seventy genotypes had 71 to 120 leaves per plant. Nine genotypes had 121 to 170 leaves per plant. While two genotypes had 171 to 220 leaves per plant.

4.2.12 Leaf length

The pattern of frequency distribution was symmetrical and unimodal with maximum number of genotypes i.e. 94 with leaf length between 10 and 12 cm. 49 genotypes had leaf length between 13 and 15 cm. 27 genotypes had leaf length between seven and nine cm. Two genotypes had leaf length between four and six cm. Fig. 4.12 shows the frequency distribution of leaf length.

4.2.13 Leaf width

The pattern of frequency distribution of leaf width (Fig. 4.13) was symmetrical and unimodal with maximum number i.e. 124 germplasm lines with leaf width in between seven and nine cm, thirty seven genotypes had leaf width between four and six cm. Ten genotypes had leaf width between ten and twelve cm. Single genotype had leaf width equal to or less than three cm.

4.2.14 Leaf weight per plant

The frequency distribution of leaf weight/plant (Fig. 4.14) pattern was unimodal and symmetrical with maximum number of genotypes i.e. ninety one genotypes had leaf weight /plant between 86 and 150 g, fifty one genotypes had leaf weight per plant between 151 and 235 g, twenty five genotypes had leaf weight/plant between 26 and 85 g. Four genotypes had leaf weight per plant between 236 and 300 g. A single germplasm line had leaf weight per plant between 301 and 365 g.

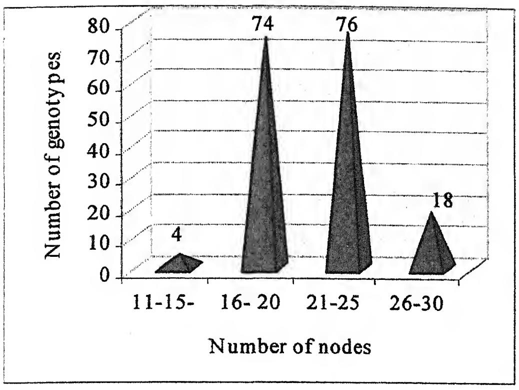


Fig. 4.7 Frequency distribution of number of nodes

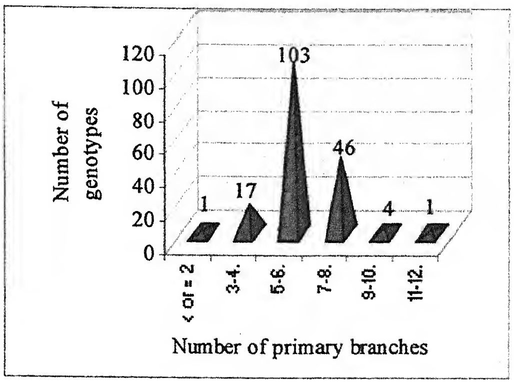


Fig. 4.8 Frequency distribution of number of primary branches per plant

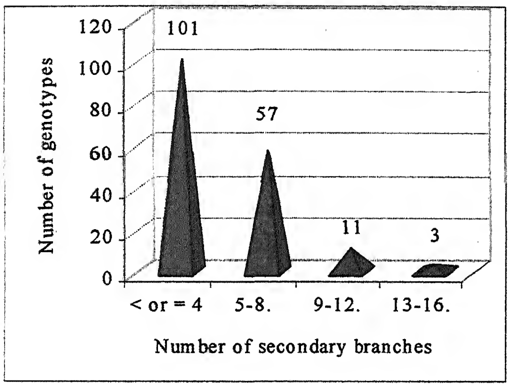


Fig. 4.9 Frequency distribution of number of secondary branches per plant

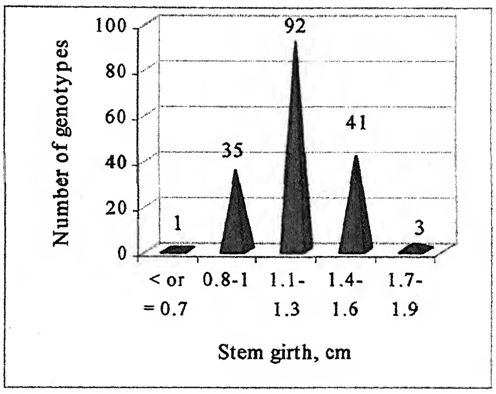


Fig. 4.10 Frequency distribution of stem girth

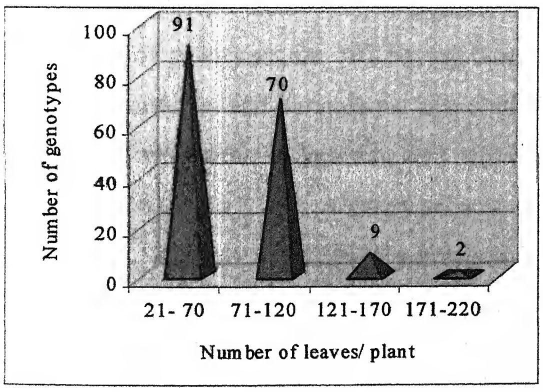


Fig. 4.11 Frequency distribution of number of leaves per plant

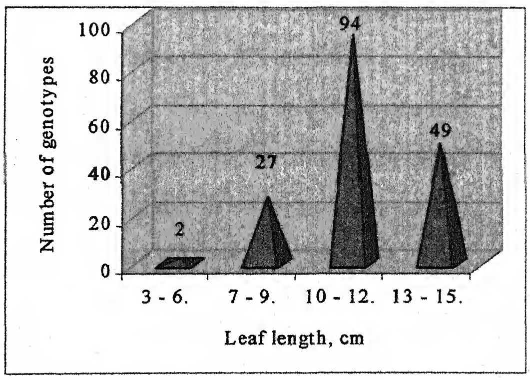


Fig. 4.12 Frequency distribution of leaf length

4.2.15 Stem weight per plant

The pattern of frequency distribution was symmetrical and unimodal with maximum number of 95 genotypes with stem weight per plant between 185 and 288 g. 52 genotypes had stem weight per plant between 81 and 184 g. Twenty one genotypes had stem weight per plant between 289 and 392 g. Two genotypes had stem weight per plant between 393 and 496 g. Two genotypes had stem weight per plant between 497 and 600 g. Fig. 4.15 shows the frequency distribution of stem weight per plant.

4.2.16 Dry leaf weight per plant

The frequency distribution was unimodal descending type with maximum number of genotypes i.e. 98 having 16 to 60 g dry leaf weight per plant. Sixty six genotypes had dry leaf weight per plant between 61 and 105 g. While seven genotypes had dry weight per plant between 106 and 150 g. A single genotype had dry leaf weight between 151 and 195 g. Fig. 4.16 shows the frequency distribution of dry leaf weight per plant.

4.2.17 Dry stem weight per plant

The pattern of frequency distribution of dry stem weight per plant (Fig. 4.17) was unimodal and symmetrical with maximum number of germplasm lines i.e. 123 having dry stem weight between 46 and 125 g. Forty genotypes had dry stem weight per plant between 126 and 205 g. Six genotypes had dry stem weight per plant between 206 and 285 g. There were no genotypes in the class with 286 to 366 g dry stem weight per plant. Two genotypes were having dry stem weight per plant in between 366 and 445 g.

4.2.18 Biomass per plant

The pattern of frequency distribution was symmetrical and unimodal with maximum number of genotypes i.e. 103 having biomass per plant in between 281 and 455 g. Forty three genotypes had biomass per plant between 106 and 280g. Twenty two genotypes had biomass per plant in between 455 and 630g. Three genotypes had biomass per plant between 631 and 815 g. A single genotype had biomass per plant in between 816 and 990 g. Fig. 4.18 shows the frequency distribution of biomass/plant.

4.2.19 L/S ratio

The pattern of frequency distribution of leaf/stem weight ratio (Fig.4.19) was symmetrical and unimodal with maximum number of genotypes i.e. 86 having L/S ratio in between 0.6 and 0.7. Forty five genotypes were found having L/S ratio in between 0.8 and 0.9. Thirty two genotypes were found having L/S ratio in between 0.4 and 0.5. Six genotypes were found having L/S ratio between 1.0 and 1.1. Three genotypes had L/S ratio in between 0.2 and 0.3.

4.2.20 Dry weight per plant

The pattern of frequency distribution of dry weight per plant (Fig. 4.20) was unimodal descending type with maximum number of genotypes i.e. 108 having dry weight per plant 61 to 180 g. 54 genotypes were found having 181 to 300 g dry weight per plant. Eight genotypes had dry weight per plant from 301 to 420 g. One genotype had dry weight per plant in between 421 and 540g. A single genotype had dry weight per plant in between 541 and 660 g.

4.2.21 Dry Leaf / Stem ratio

The pattern of frequency distribution of dry leaf/stem weight ratio (Fig. 4.21) was unimodal and symmetrical. The maximum number of genotypes i.e. 76 were having dry L/S ratio from 0.5 to 0.6. Fifty three genotypes had dry L/S ratio between 0.7 and 0.8. Twenty nine genotypes had L/S ratio in between 0.3 and 0.4. Thirteen genotypes had dry L/S ratio between 0.9 and 1.0. A single genotype had dry L/S ratio between 1.1 and 1.2.

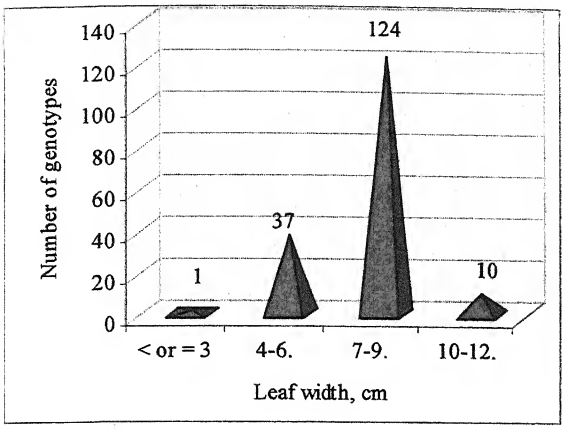


Fig. 4.13 Frequency distribution of leaf width

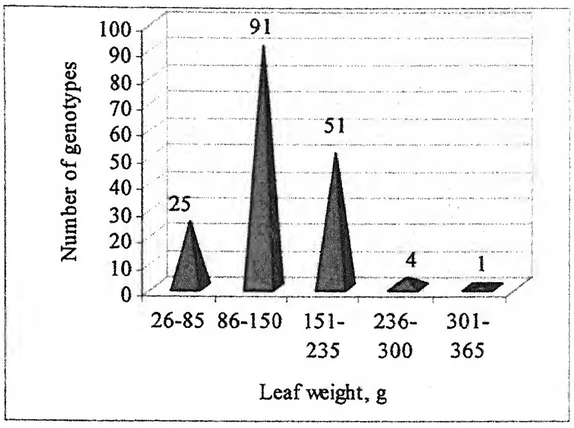


Fig. 4.14 Frequency distribution of leaf weight per plant

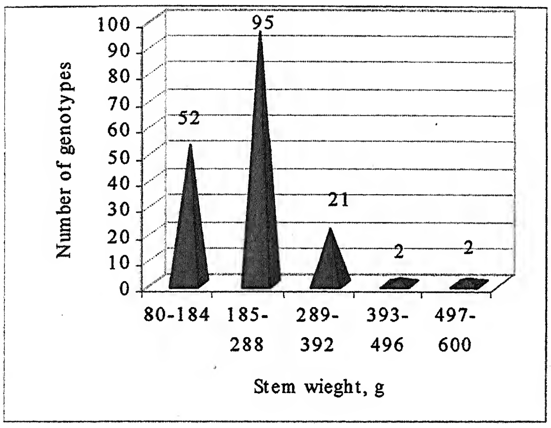


Fig. 4.15 Frequency distribution of stem weight per plant

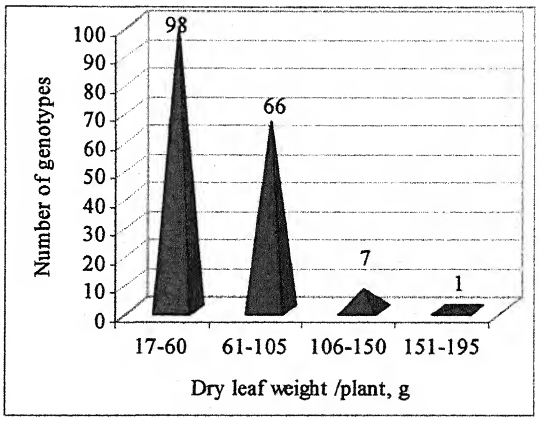


Fig. 4.16 Frequency distribution of dry leaf weight per plant

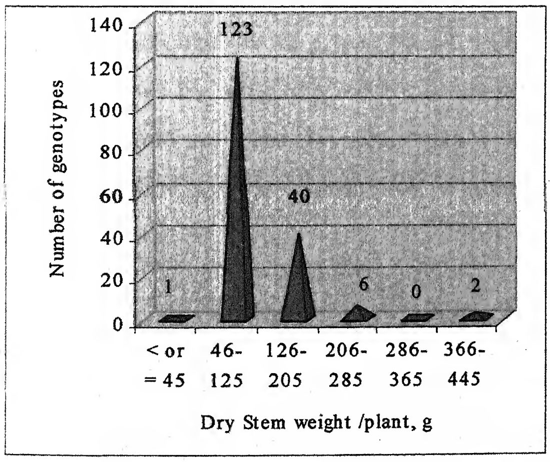


Fig. 4.17 Frequency distribution of dry stem weight per plant

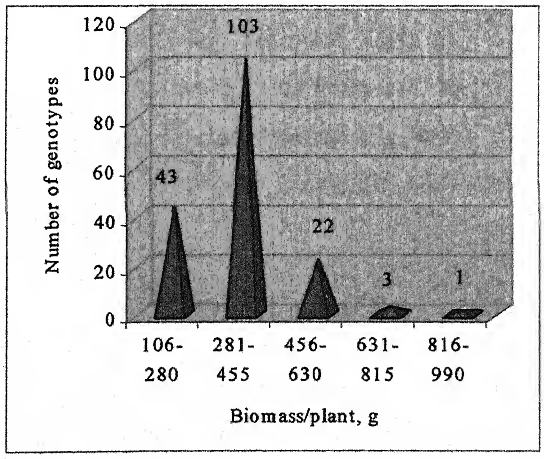


Fig. 4.18 Frequency distribution of biomass per plant

4.2.22 100 Seed weight

The pattern of frequency distribution was unimodal and symmetrical with maximum number of genotypes i.e. 107 having 100 seed weight in the range 13 to 18 g. Forty one genotypes were found having 100 seed weight in the range seven to twelve g. A single genotype had 100 seed weight in between 25 and 30 g. Fig. 4.22 shows the frequency distribution of 100 seed weight.

4.2.23 Days to maturity initiation

The pattern of frequency distribution of days to maturity initiation (Fig. 4.23) was unimodal and symmetrical. The maximum number of genotypes i.e. 88 were found having 61 to 80 days to maturity initiation. 42 genotypes were found to have days to maturity initiation in between 81 and 100 days. Forty one genotypes had days to maturity initiation in between 101 and 120 days. While a single genotype had days to maturity initiation either equal to or less than 60 days.

4.2.24 Days to total maturity

The pattern of frequency distribution of days to total maturity (Fig. 4.24) was unimodal and symmetrical with maximum number of genotypes i.e. 99 having total days to maturity in between 131 and 140. 37 genotypes had total days to maturity in between 141 and 150. 23 genotypes had total days to maturity in between 121 and 130, while 13 genotypes had total days to maturity in between 111 to 120.

4.2.25 Number of clusters per plant

The pattern of frequency distribution was unimodal and descending type with maximum number of genotypes i.e. 110 having two to eight clusters per plant. Forty six genotypes had nine to sixteen clusters per plant. Ten genotypes were found to have 17 to 24 clusters per plant. Six genotypes were found to have 25 to 32 clusters/plant. Fig. 4.25 shows the frequency distribution of number of clusters/plant.

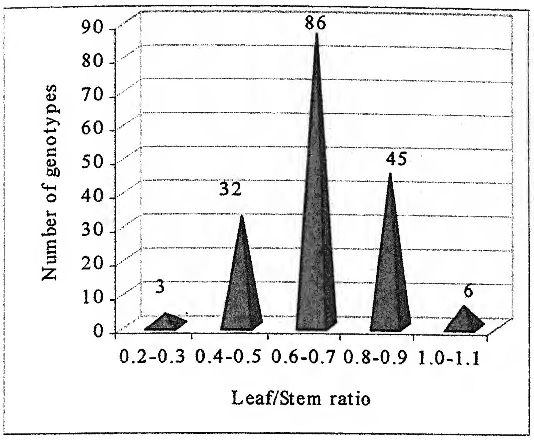


Fig. 4.19 Frequency distribution of Leaf/ Stem ratio

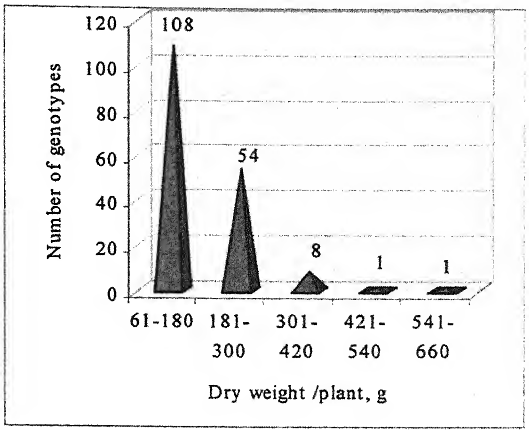


Fig. 4.20 Frequency distribution of dry weight per plant

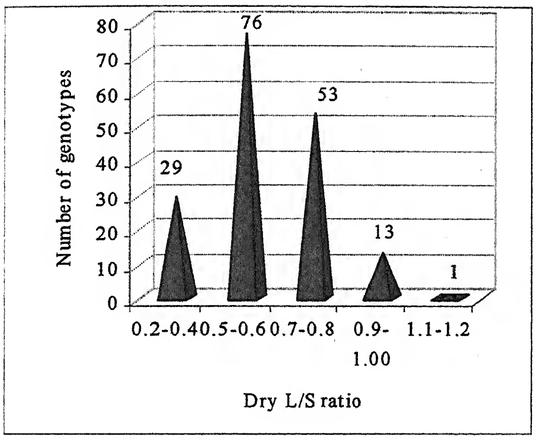


Fig. 4.21 Frequency distribution of dry Leaf/ Stem ratio

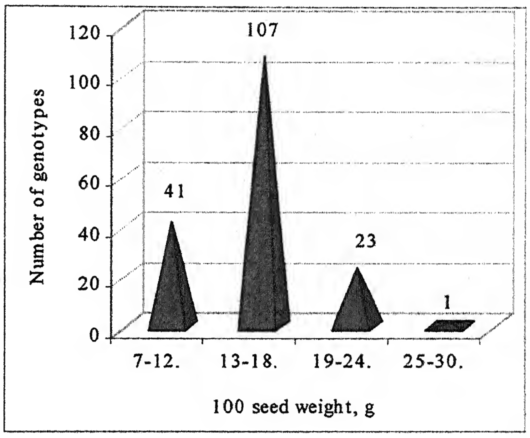


Fig. 4.22 Frequency distribution of 100 seed weight

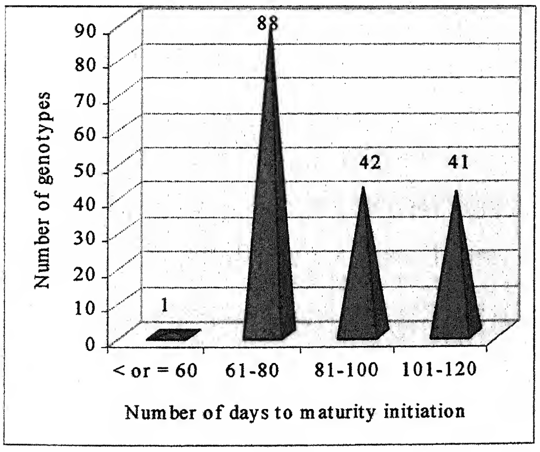


Fig. 4.23 Frequency distribution of days to maturity initiation

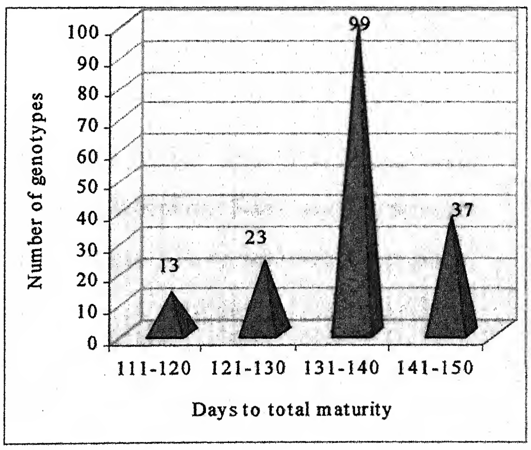


Fig. 4.24 Frequency distribution of days to total maturity

4.2.26 Number of pods per plant

The pattern of frequency distribution of number of pods/plant (Fig. 4.26) was unimodal and symmetrical with maximum number of genotypes i.e. 73 with six to fifteen pods per plant. Forty eight germplasm lines had sixteen to twenty five pods/ plant. Twenty four germplasm lines had 26 to 35 pods per plant. Seventeen genotypes had a total of 36 to 45 pods per plant. While five genotypes had 46 to 55 pods per plant. Another five genotypes had six to fifteen pods per plant.

4.2.27 Pod length

The pattern of frequency distribution was unimodal and symmetrical with maximum number i.e. 101 germplasm lines with pod length eleven to fifteen cm. Fifty nine genotypes had pod length in between 16 and 20 cm. Eight genotypes had pod length in between six and ten cm. Four germplasm lines had long pods in the range 21 to 25 cm. Fig. 4.27 shows the frequency distribution of pod length.

4.2.28 Seeds per pod

The pattern of frequency distribution of seeds/pod (Fig.4.28) was unimodal and symmetrical. The maximum number of genotypes i.e. 85 were found having thirteen to sixteen seeds per pod. Fifty genotypes were found having 9 to 12 seeds per pod. Thirty one genotypes were found having seventeen to twenty seeds per pod. Three genotypes were found having 21 to 24 seeds per pod. Three genotypes were also found having five to eight seeds per pod.

4.2.29 Seeds per plant

The pattern of frequency distribution was unimodal and descending with maximum number of 74 genotypes with 31 to 180 seeds per plant. Forty eight genotypes had 181 to 330 seeds per plant. Twenty six genotypes had 331 to 480 seeds per plant. Seventeen genotypes had 481 to 630 seeds per plant. Seven germplasm lines had 631 to 780 seeds per plant. Fig. 4.29 shows the frequency distribution of seeds/plant.

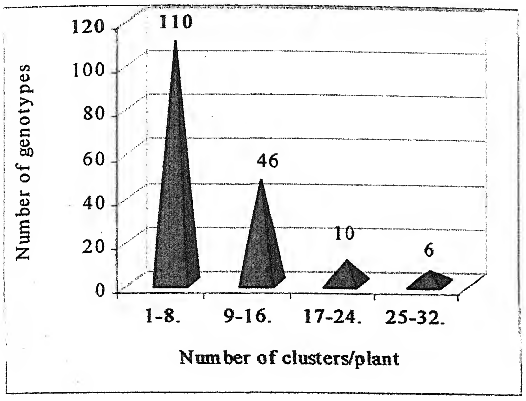


Fig. 4.25 Frequency distribution of number of clusters per plant

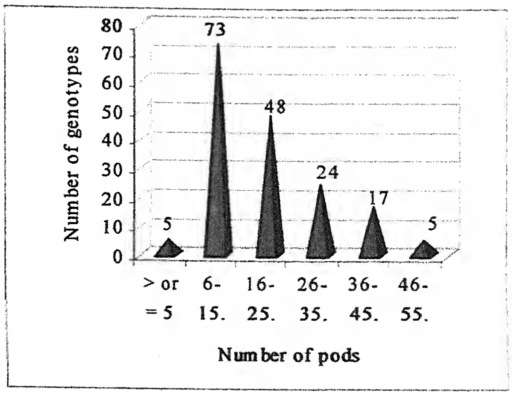


Fig. 4.26 Frequency distribution of number of pods per plant

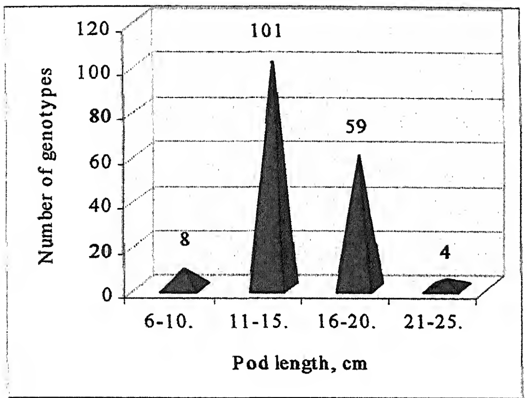


Fig. 4.27 Frequency distribution of pod length

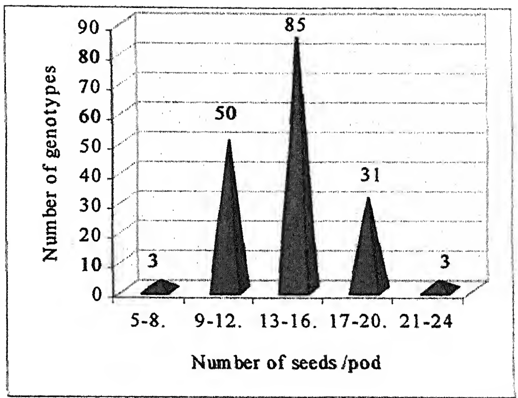


Fig. 4.28 Frequency distribution of number of seeds per pod

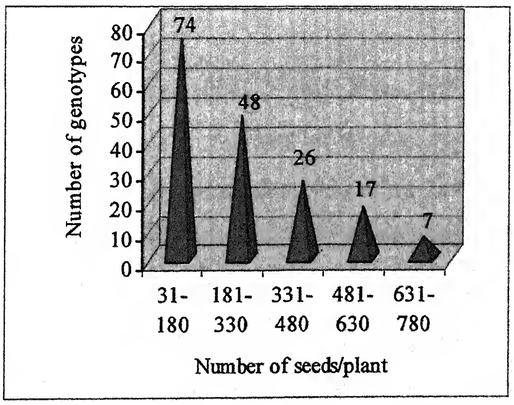


Fig. 4.29 Frequency distribution of number of seeds per plant

4.3 Clustering pattern based on 1st year data

A total of 172 lines were evaluated in the year 2004-05 as numbered from 1 to 172 in Table 3.1 of Chapter 3. The morphological data was collected for 29 traits. Trait wise data recorded for these lines are shown in Appendix A. Cluster analysis was performed with these data. Table 4.1 shows the accessions grouped in different clusters during the year 2004-05. 172 germplasm lines clustered into 12 clusters for 20 trait variables. As revealed by Table 4.1, the 7th cluster was the largest with 33 lines and 10th was the smallest with 2 germplasm lines in this clustering pattern.

Table 4.2 shows morphological character's mean and standard deviation for different clusters during the year 2004-05.

The genotypes in cluster number 6 flowered most late where mean value of 50 % days to flowering was 83.17± 1.47 days and earliest flowering genotypes were in cluster number 1 with mean value of 50 % days to flowering 45.93 ± 4.69 days.

The genotypes in cluster number 6 also had a maximum span of days to total flowering, mean value being 102.83± 0.75 days and shortest span was of genotypes in cluster number 1 i.e. 63.64 ± 9.12 days.

The tallest lines were grouped in cluster number 11 with a mean of 271.67 ± 27.05 cm, the shortest lines were grouped in cluster number 4 with a mean of 151.44± 27.94 cm.

The lines with a maximum number of nodes were grouped in cluster number 12 with a mean of 28.47 ± 3.99 nodes per plant. Genotypes with minimum number of nodes were grouped in cluster number 6 with mean value 17.18± 3.81 nodes per plant.

Genotypes in cluster number 10 were more branched with maximum mean value of number of primary branches and number of secondary branches i.e. 8.48 ± 0.48 primary branches and 15.59± 4.82 secondary branches per plant respectively. These genotypes were also thick stemmed with maximum mean values 2.26± 0.35 cm.

Genotypes in cluster number 3 were least branched with minimum mean value of primary and secondary branches per plant i.e. 3.83 ± 0.97 primary branches and 2.91± 1.12 secondary branches per plant. These genotypes were also thin stemmed with minimum mean value 0.95 ± 0.10 cm.

The genotypes in cluster number 10 also had maximum number of leaves / plant i.e. mean value of 323.95± 67.81 leaves, where as minimum number of leaves / plant was shown by cluster 11 with mean value 53.74± 15.89 leaves.

The highest leaf length was of lines in cluster number 12 where mean value was 13.88 ± 0.82 cm and the smallest leaf length mean value was of lines in cluster number 8 i.e. 8.66 ± 1.12cm.

The highest mean value of leaf width was shown by genotypes of cluster number 2 i.e. 10.98 ± 1.19 cm and lowest by lines of cluster number 6 i.e. 6.24 ± 1.91 cm.
Leaf weight per plant was again highest amongst lines of cluster number 10 with maximum mean value 417.05± 123.63 g while minimum mean value was 81.58 ± 30.16 g amongst genotypes of cluster number 3.

The maximum mean value of stem weight per plant was 655.15 ± 76.58 g in cluster number 10 lines and minimum amongst genotypes of cluster number 3 i.e. 143.39± 42.01 g.

The higher fodder yielding lines were clubbed in cluster number 10 with maximum mean value of fresh biomass/plant, 1072.20 ± 47.05 g and minimum by cluster number 3 i.e. 224.97 ± 69. 10 g. Also dry wt /plant had maximum mean value of 765.28 ± 79.29 g in cluster number 10 and minimum of 120.94 ± 39.69 g in cluster number 3.

The longest span of pod maturity was shown by cluster number 6 with maximum mean value of days to total maturity 141.83 ± 8.80 days and minimum span of maturity by cluster number 3 genotypes i.e. 123.88 ± 8.28 days.

The maximum number of pods and pod clusters per plant bearing genotypes were clubbed in cluster number 5 with mean value 43.12 ± 9.51 pods and 18.05 ± 6.36 pod clusters respectively and minimum mean value was shown by cluster number 4 i.e. 7.54 ± 43.12 pods and 3.60 ± 2.72 pod clusters respectively.

The longest pod bearing genotypes with maximum mean value of pod length 17.10 ± 5.10 cm were grouped in cluster number 11 and shortest pod bearing lines were grouped in cluster number 3 with minimum mean value 10.81± 1.01 cm.

The highest number of seeds /pod bearing lines were in cluster number 11 with mean value of 16.46 ± 3.81 seeds and lowest number of seeds/pod - bearing lines were in cluster number 4 with mean value 9.89±2.74 seeds.

The highest number of seeds / plant was in cluster number 5 i.e. mean value 610.72 ± 105.66 seeds and minimum was 124.95 ±54.71seeds in cluster number 4.

Table 4.3 shows the distance between centroids of twelve clusters taken during the year 2004-05. The maximum average distance of cluster members from cluster centroids was 3.342 and minimum was 2.377 of clusters 11 and 12 respectively. The maximum distance between cluster centroids was observed between cluster 3 and 10 i.e. 13.059 followed by between 1 and 11 i.e. 12.419. The minimum distance was between cluster 1 and 3 i.e. 2.639.

Table 4.1 Accessions grouped in different clusters during the year 2004-05

Cluster number	Accessions (Names of accessions are given corresponding to its number in Table 3.1)
1	6 , 9 10 12 13 16 18 20 24 25 29 37 39 44 45 52 59 65 79 91 123 127 132 133 141 151 157 159
2	1 5 19 84 85 110 112 113 161 162 165 166
3	8 34 55 61 62 63 64 66 67 68 69 70 94 108 129 134 172
4	2 14 17 26 99 124 126 142 155
5	7 56 58 73 75 76 87 106 118 128 140 143 145 146 152 153 154 163
6	31 40 104 107 109 116
7	3 4 11 22 28 32 33 35 50 51 53 54 57 71 77 78 82 83 86 90 93 95 98 100 114 136 147 148 156 164 168 170 171
8	27 30 46 49 81 96 101 102 120 125 135 150
9	15 21 23 36 38 41 48 74 80 88 97 115 119 122 130 131 137 138 139 144 149 158 169
10	103 121
11	42 43 47 60 72 89 92 160
12	105 111 117 167

Table 4.2 Morphological character's mean and standard deviation for different clusters during the year 2004-05

Clustr No.	Days to 50% flower	Days to total flower	Plant height	No. of nodes	No. of primy branch	No. of Secry branch	Stem girth	Leave Per plant	Leaf length	Leaf width	Leaf weight Per plant	Stem weight per plant	Dry stem weight plant	Dry weight per plant	Days to total maturity	No. of pod cluster per plant	No. of pods per plant	Pod length	No. of Seeds per pod	No. of Seeds per plant
1	45.93± 4.69	63.64± 9.12	165.1± 36.41	18.35± 2.93	5.06± 0.97	3.27± 1.39	1.34± 0.25	71.20± 18.92	13.22± 0.97	9.86± 0.88	151.8± 34.09	218.85 ±51.16	370.70 ±77.33	171.9± 43.83	129.1± 10.01	5.15± 2.50	14.43± 5.51	14.17± 2.15	12.78± 2.04	184.4± 74.52
2	50.75± 4.49	72.08± 13.17	201.44 ± 44.31	26.44± 3.02	7.45± 1.05	6.71± 2.88	1.63± 0.28	126.13 ± 36.13	13.71± 1.71	10.98± 1.19	262.22 ±46.74	397.32 ± 76.45	659.54 ± 110.05	360.36 ± 102.11	127.92 ± 8.37	4.42± 2.65	11.13± 5.27	13.83± 3.21	10.99± 2.07	126.01 ± 73.92
3	49.75± 4.93	66.74± 9.40	172.39 ± 29.71	17.65± 2.75	3.83± 0.97	2.91± 1.12	1.13± 0.18	59.46± 16.67	12.92± 1.32	9.04± 1.35	81.58± 30.16	143.39 ± 42.01	224.97 ± 69.10	120.94 ± 39.69	123.88 ± 8.28	7.12± 3.57	21.54± 10.73	10.81± 1.01	10.03± 1.69	214.69 ± 113.12
4	57.11± 10.08	68.44± 9.65	151.44 ± 27.94	23.14± 2.49	7.99± 1.21	15.40± 3.89	1.53± 0.22	186.73 ± 36.36	12.35± 1.16	9.53± 1.16	254.93 ±72.11	410.10 ± 77.41	665.03 ± 136.48	349.84 ± 103.68	128.89 ± 5.82	3.60± 2.72	14.00± 7.54	11.83± 3.15	9.89± 2.74	124.95 ± 54.71
5	49.11± 4.07	68.72± 15.39	159.57 ± 27.26	21.26± 3.39	6.53± 1.55	3.76± 1.93	1.37± 0.10	97.54± 27.51	13.07± 1.18	9.34± 1.31	182.80 ±29.07	275.19 ± 42.66	457.99 ± 60.53	220.52 ± 46.93	132.06 ± 7.30	18.05± 6.36	43.12± 9.51	14.99± 2.29	14.65± 3.35	610.72 ± 105.66
6	83.17 ±1.47	102.8 ±0.75	153.44 ±22.1	17.18± 3.81	4.77± 1.32	3.65± 2.17	0.95± 0.10	99.54± 57.97	8.75± 2.93	6.24± 1.91	93.58± 40.9	223.20 ±78.00	316.78 ±113.9	215.07 ± 97.94	141.83 ± 8.80	6.82± 4.20	10.08± 7.99	13.83± 1.44	14.39± 1.23	144.72 ± 109.4
7	57.49± 12.78	74.82± 14.99	167.53 ± 33.48	21.58± 3.34	7.16 ± 1.17	5.67 ± 2.19	1.41± 0.22	100.49 ± 21.94	11.87± 1.06	8.45 ± 0.76	142.28 ± 41.29	256.60 ± 55.50	398.88 ± 70.23	197.30 ± 39.11	132.38 ± 12.05	4.95 ± 2.42	12.11± 6.23	11.66± 1.68	11.02 ±2.27	135.90 ± 78.21
8	82.67± 4.33	100.75 ± 8.15	178.45 ± 33.48	24.66± 3.44	7.00± 1.64	10.02± 4.12	1.48± 0.32	194.52 ± 47.81	8.66± 1.12	6.53± 1.13	164.9± 34.1	368.30 ±78.39	533.25 ±98.22	366.07 ± 77.34	140.75 ± 10.15	3.87± 2.09	10.59± 4.94	13.01± 1.70	12.26± 2.48	126.79 ± 54.06
9	47.43± 7.60	73.14± 15.34	159.66 ± 30.63	19.08± 1.99	7.18± 1.15	5.74± 3.08	1.58± 0.27	115.47 ± 34.70	13.69± 1.34	9.55± 0.83	219.6± 38.5	327.96 ±42.95	547.60 ±68.68	264.11 ± 52.84	133.13 ± 9.38	8.07± 3.92	21.19± 9.53	13.89± 1.64	13.50± 2.08	278.09 ± 116.24
10	71.50± 16.26	89.00± 19.80	215.20 ± 50.40	26.97 ±0.71	8.48 ±0.48	15.59 ±4.82	2.26 ±0.35	323.95 ±67.81	11.53± 3.52	8.20 ±1.55	417.05 ±123.6 3	655.15 ±76.58	1072.2 0 ±47.05	765.28 ±79.29	140.50 ±13.44	4.98 ±5.66	8.58 ± 4.99	13.02± 2.74	13.33 ±4.87	126.44 ± 108.26
11	53.12 ±6.62	65.25 ±4.86	271.67 ±27.05	20.05 ±3.43	4.85 ±0.87	3.35 ±2.27	1.09 ±0.16	53.74 ±15.89	13.56 ±1.65	9.53 ±1.29	103.68 ±54.71	191.83 ±74.12	295.51 ±126.4 9	137.86 ±39.98	132.12 ±14.11	6.92 ±2.77	13.64 ±5.64	17.10 ±5.10	16.46 ±3.81	215.09 ±80.31
12	49.25± 4.92	90.75 ±10.47	215.29 ±29.20	28.47 ±3.99	6.57 ±0.91	4.71 ±1.43	1.67 ±0.13	165.74 ±87.46	13.88 ±0.82	10.40 ±0.73	296.37 ±23.48	484.86 ±61.15	781.24 ±69.60	441.40 ±65.36	141.50 ±6.61	13.53 ±4.90	32.92 ±4.68	15.89± 1.27	15.12 ±3.84	484.43 ± 54.83

Table 4.3 Distance between centroids of twelve clusters during the year 2004-05

Cluster	1	2	3	4	5	6	7	8	9	10	11	12
1	0.000											
2	4.623	0.000										
3	2.639	6.450	0.000									
4	5.639	3.269	6.996	0.000								
5	4.556	5.858	5.340	6.572	0.000							
6	5.445	7.565	5.417	7.417	6.831	0.000						
7	2.645	4.033	3.558	4.317	5.033	4.555	0.000					
8	6.504	5.582	7.314	4.712	7.213	4.566	4.498	0.000				
9	2.897	3.152	4.846	3.969	3.631	6.073	2.897	5.504	0.000			
10	11.46	7.755	13.06	7.058	11.19	11.80	10.21	7.793	9.181	0.000		
11	3.426	6.031	4.286	7.476	5.462	5.864	4.611	7.323	4.952	12.41	0.000	
12	6.850	4.386	8.475	5.862	5.112	8.587	6.592	6.654	4.675	7.382	7.397	0

4.4 Clustering pattern based on 2nd year data

In year **2005-06**, 172 germplasm lines (names given in Table 3.1 of Chapter 3) were evaluated whose morphological data is shown in Appendix B. On performing cluster analysis, these 172 lines grouped into 13 clusters for 20 trait variables. Table 4.4 shows the accessions grouped in different clusters during the year 2005-06. In this clustering pattern 1st and 7th clusters were largest with 25 germplasm lines each and cluster 3 was smallest with 2 lines.

Table 4.5 shows morphological character's mean and standard deviation for different clusters during the year 2005-06.

The genotypes in cluster number 7 flowered the most late where mean value of 50 % days to flowering was 68.73 ± 7.33 days and early flowering lines with minimum mean value 43.00 ± 0.00 days were grouped in cluster number 3.

Also the lines with maximum span of days to total flowering, mean value 91.28± 6.74 days were grouped together in cluster number 7 and minimum mean value 64.0± 0.00 days were grouped in cluster number 3.

The taller lines were grouped in cluster number 6 with maximum mean value 188.83± 35.81 cm and shorter lines with minimum mean value 122.66± 15.64 cm were grouped in cluster number 13.

The maximum mean value of number of nodes / plant was 25.28 ± 4.20 nodes in cluster number 2 and minimum mean value was 16.87 ± 3.36 nodes in cluster number 13. The highest mean value of number of primary branches per plant was in cluster number 4 i.e. 8.72 ± 1.92 branches and minimum in cluster number 3 i.e. 2.53 ± 0.00 branches.

The lines with highest mean value of number of secondary branches/plant, 13.00 ± 0.00 branches were grouped in cluster number 3 and lowest mean value 1.00 ± 0.26 were grouped in cluster number 8.

The highest mean value of 1.27± 0.22 of stem girth was in cluster number 12 and lowest of 0.62 ± 0.08 in cluster number 3.

The lines with maximum mean value of number of leaves / plant 87.84 ± 33.75 were grouped in cluster number 4 and lowest mean value of 25.56 ± 13.96 were clubbed in cluster number 13.

The highest mean value of leaf length /plant i.e. 13.68± 1.81 was in cluster number 12 and lowest value of 5.64 ± 1.76 in cluster number 13 genotypes. The highest mean value of leaf width / plant i.e. 7.95 ± 2.38 was of cluster number 4 genotypes and lowest mean value of cluster number 13 genotypes i.e. 2.80± 1.66 cm.

The germplasm lines with a maximum fodder yield i.e. fresh and dry biomass per plant were grouped in cluster number 8 with mean value 543.43 ± 150.93g and 344.57 ± 131.65g respectively. The lines with minimum fresh and dry biomass per plant were grouped in cluster number 13 with mean value of 192.81 ± 61.34 g and 85.33 ± 31.34 g respectively.

The lines with heavy seeds were clubbed in cluster number 2 with maximum mean value of 100 seed weight 19.85 ± 3.46 g and lightest seeds bearing lines were grouped in cluster number 13 with mean value 10.88 ± 2.51g.

The late maturity initiation was observed in genotypes of cluster number 7 with highest mean value of 113.05 ± 15.43 days and earliest maturity initiation was observed in genotypes of cluster number 4 with mean value 75.40 ± 8.05 days.

The maximum span of days to total maturity was in lines of cluster number 2 with mean value of 146.33 ± 8.91 days and minimum span to total maturity was observed in lines of cluster number 3 with mean value of 121.50± 13.44 days.

The maximum number of pods and pod clusters per plant bearing genotypes were clubbed in cluster number 10 with mean value 41.48 ± 5.86 pods and 20.15 ± 7.04 pod clusters respectively and minimum number of pods and pod clusters per plant bearing genotypes were clustered in cluster number 3 with a mean value of 10.93± 4.64 pods and 4.16 ± 1.47 pod clusters respectively.

The longest pod bearing lines were observed in cluster number 6 with a mean value of 21.59 ± 2.99 cm and shortest pods with a mean value of 11.38± 1.72 cm were clustered in cluster number 9.

The maximum number of seeds per pod was observed in lines grouped in cluster number 6 with mean value of 19.67 ± 2.46 seeds and minimum mean value of 10.08 ± 1.91 seeds in genotypes of cluster number 9.

The highest number of seeds /plant was observed in lines of cluster number 10 with maximum mean value of 629.78±85.96 seeds and lowest value of 108.38 ± 48.25 seeds in cluster number 11.

Table 4.6 shows the distance between centroids of twelve clusters taken during the year 2005-06. The maximum distance between cluster centroids was observed between 3 and 10 i.e. 8.128 followed by between 3 and 6 i.e. 7.924 and between 8 and 10 i.e. 7.563. The maximum average distance of cluster members from cluster centroids was of cluster number 8 i.e. 3.920 and minimum average distance was of cluster number 3 i.e. 2.039.

Table 4.4 Accessions grouped in different clusters during the year 2005-06

Cluster number	Accessions (Names of accessions are given corresponding to its number in Table 3.1)
1	6 10 13 24 25 32 36 37 38 42 44 45 50 51 52 60 71 79 80 86 88 138 157 159 170
2	2 16 57 77 91 92
3	4 5
4	9 15 18 23 59
5	7 21 48 55 72 87 94 111 119 122 128 131 132 140 144 146 152 153 167
6	1 19 20 43 89 105
7	22 27 28 31 40 81 96 100 101 102 104 110 112 113 114 115 120 130 135 136 137 149 150 160 171
8	74 103 121 133 166
9	54 61 62 64 67 68 70 90 93 99 123 142 151 172
10	56 58 69 73 75 76 97 106 107 108 117 118 143 145 154 163
11	26 35 41 47 49 78 85 98 124 134 161 165
12	3 11 14 17 29 33 39 46 53 84 109 116 126 127 129 139 141 169
13	8 12 30 34 63 65 66 82 83 95 125 147 148 155 156 158 162 164 168

Table 4.5 Morphological character's mean and standard deviation for different clusters during the year 2005-06

Clustr No.	Days to 50% flower	Days to total flower	Plant height	No. of nodes	No. of primy branch	No. of Secry branch	Stem girth	Leave Per plant	Leaf length	Leaf width	Leaf weight Per plant	Stem weight per plant	Dry stem weight plant	Dry weight per plant	Days to total maturity	No. of pod cluster per plant	No. of pods per plant	Pod length	No. of Seeds per pod	No. of Seeds per plant
1	47.10 ± 6.60	64.22± 8.76	141.00 ±29.80	17.98 ±3.40	3.90 ±1.14	2.25 ± 1.00	0.84 ±0.15	31.92 ±10.18	7.61±2.40	3.37 ±0.88	219.80 ±55.03	93.47 ±29.09	17.23 ±2.66	79.93 ±7.63	135.51 ±9.75	6.69 ±2.99	17.06 ±6.86	16.22± 2.12	15.83 ±2.72	267.69 ±111.95
2	45.67 ±5.13	67.67± 3.20	182.40 ±37.28	25.28 ±4.20	5.00 ±1.97	4..57 ±1.32	0.83 ±0.19	53..75 ±12.08	11.8.2 ±3.15	7.70 ±1.59	286.76 ±88.35	113.11 ± 20.57	19.85 ±3.46	79.00 ±7.75	146.33 ±8.91	6.46 ±2.67	11.30 ±4.95	15.38± 2.30	16.21 ±2.79	187.39 ±93.28
3	43.00 ±0.00	64.00 ±0.00	132.72 ±23.15	19.64 ±3.09	2.53 ± 0.00	13.00± 0.00	0.62 ±0.08	38.12 ±8.31	6.13± 1.77	3.28± 1.78	274.91 ±10.71	91.57 ±15.27	12.69± 5.81	88.50 ±14.85	121.50 ±13.44	4.16 ±1.47	10.93± 4.64	13.69± 2.09	14.35 ±2.43	162.56 ± 93.20
4	49.80 ±6.50	66.40 ±1.52	126.39 ±24.23	21.71 ±1.93	8.72 ±1.92	6.38 ±2.42	1.14 ±0.18	87.84 ±33.75	12.93± 2.40	7.95 ±2.38	256.32 ±81.22	161.47 ±64.01	14.49 ±3.16	75.40 ±8.05	142.80 ±7.79	5.18 ±3.08	19.23 ±8.88	14.51± 3.58	18.52 ±2.02	358.30 ±181.69
5	51.63 ±11.06	73.42 ±12.83	144.68 ±31.86	19.34 ±2.40	4.02 ±1.38	2.69 ±1.33	0.89±0.16	31.03 ±7.13	7.49 ±1.98	3.85 ±1.05	255.82 ±89.32	92.86 ±21.57	16.00 ±3.13	90.84 ±17.61	138.42 ±7.48	15.43± 5.66	36.95 ±6.01	16.01± 2.17	14.92 ±1.65	546.20 ±76.69
6	47.00± 7.01	65.17 ±1.60	188.83 ±35.81	24.75 ±5.04	5.30 ±2.16	2.06 ±0.81	1.03 ±0.13	48.92 ±14.11	12.99± 1.60	5.45 ±1.67	266.94 ±66.50	121.20 ±34.65	17.73 ±1.67	84.33 ± 16.33	124.00 ± 7.69	9.48 ±3.58	24.18 ±10.11	21.59± 2.99	19.67 ±2.46	468.91 ± 190.10
7	68.73 ±7.33	91.28 ±6.74	136.35 ±29.62	20.79 ±2.89	4.47 ±1.47	2.67 ± 1.25	1.05±0.20	34.12± 15.52	7.59± 2.39	3.58 ±1.38	257.71 ±60.61	107.20 ±49.58	17.26± 2.71	113.05 ±15.43	141.91 ±8.23	5.29 ±2.40	12.02± 5.11	15.27± 1.89	14.82 ±2.50	177.82 ± 83.84
8	65.80 ±5.02	88.80± 5.02	128.09 ± 17.21	18.76 ± 1.36	4.56 ±2.65	5.82 ± 2.50	1.00±0.26	34.08 ±15.16	8.38± 1.36	4.36 ±1.63	543.43 ±150.93	344.57 ±131.65	15.23 ±1.20	94.20 ±19.84	134.20 ±10.50	6.14 ±3.26	14.15 ± 5.96	16.11± 2.28	15.46 ±3.90	226.47 ± 116.74
9	50.60 ±7.52	68.10 ±6.16	150.10 ±22.40	21.51± 4.70	4.20 ±1.01	2.51 ±0.88	0.91 ±0.19	53.30 ±24.24	9.11± 2.19	5.61 ±1.55	211.34 ±70.95	89.31 ±16.89	11.82 ±2.35	82.76 ±11.99	125.75 ±7.04	8.67 ±3.32	23.69 ±5.60	11.38± 1.72	10.08 ±1.91	242.24 ±84.80
10	48.44 ±7.38	72.44 ±11.06	173.04 ±44.12	23.32 ±5.01	4.63 ±2.06	1.83 ± 0.94	1.04±0.21	43.87 ±12.90	9.93± 1.70	5.59± 1.42	235.32 ±46.95	97.25 ±25.83	15.09 ±2.93	88.69 ±17.10	137.88 ±10.39	20.15 ±7.04	41.48 ± 5.86	15.90± 3.58	15.34 ±2.32	629.78 ±85.96
11	55.33 ±12.15	74.08 ±11.21	138.44 ±35.96	18.82 ±3.30	4.63 ±1.75	3.62 ±1.49	1.02 ±0.25	36.95 ±18.13	12.08± 1.81	6.00± 2.19	286.83 ±58.02	107.39 ±38.03	15.80± 3.41	92.83 ±16.92	136.50 ± 6.99	5.02 ±3.43	11.34 ±6.50	11.94± 2.27	10.44 ±2.36	108.38 ±48.25
12	66.21 ±10.25	81.93 ±11.20	145.84 ±30.65	21.95 ±3.05	5.89 ±1.90	3.41 ±1.18	1.27±0.22	51.76 ±18.24	13.68± 1.81	7.02 ±2.20	276.31 ±47.48	138.21 ±33.81	18.24 ±3.08	91.99 ±11.75	138.13 ±12.20	6.92 ±3.62	16.51 ±10.05	14.82± 2.01	14.62 ±2.43	231.56 ±123.26
13	60.42± 10.99	78.11 ±11.42	122.66 ± 15.64	16.87 ± 3.36	3.10 ± 1.17	1.75 ± 1.00	0.75±0.22	25.56± 13.96	5.64± 1.76	2.80 ±1.66	192.81 ±61.34	85.33 ±31.34	10.88 ±2.51	86.68 ±16.94	134.95 ± 7.56	6.60 ±2.05	13.59 ± 5.82	12.50± 1.82	12.18 ±2.55	165.83 ± 82.11

Table 4.6 Distance between centroids of thirteen clusters during the year 2005-06

Clusters	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.000												
2	4.011	0.000											
3	6.195	6.635	0.000										
4	5.716	4.147	7.295	0.000									
5	2.945	4.888	6.942	6.025	0.000								
6	4.255	4.175	7.924	5.312	4.383	0.000							
7	3.741	4.787	7.072	6.158	4.180	5.582	0.000						
8	6.591	6.639	7.514	6.813	6.648	7.138	5.682	0.000					
9	3.559	4.580	6.319	5.507	3.938	5.342	4.617	7.107	0.000				
10	4.382	4.976	8.128	5.829	2.226	3.903	5.350	7.563	4.315	0.000			
11	3.551	3.782	6.211	5.134	4.512	5.648	3.399	5.878	2.895	5.323	0.000		
12	4.406	3.495	7.496	4.027	4.638	4.462	3.378	5.655	4.269	4.742	2.855	0.000	
13	3.163	5.882	6.484	7.090	4.172	6.606	3.671	6.943	3.375	5.696	3.685	5.357	0.000

4.5 Cytology

4.5.1 Pollen fertility

Fresh pollen was dusted on a glass slide and visualized in a drop of aceto-glycero carmine. The number of fertile and sterile pollens was counted for 25 microscopic views and the ratio calculated, data was then converted into percent pollen fertility. Maximum percent pollen fertility was shown by accessions of cultigroup *sesquipedalis* i.e. EC 548873 with 96%, followed by EC 548867 with 95% fertile pollens. Minimum percent pollen fertility was shown by line IVM-1 of cultigroup *unguiculata* with 80% fertile pollens. Table 4.15 shows percent Pollen fertility of cowpea germplasm lines.

4.5.2 Types of associations

The meiotic studies carried out in Pollen mother cells (PMCs) of three cultigroups of Cowpea i.e. *V. unguiculata* cv.gr. *unguiculata* (accessions, EC548999 and IL-1177), *V. unguiculata* cv.gr. *sesquipedalis* (accession, EC 548875) and *V. unguiculata* cv.gr. *cylindrical* (accession, IC 438864). Chromosome associations were noted during diakinesis, metaphase and anaphase in these accessions. All the accessions showed a uniform chromosome number of 2n=22. Meiotic studies revealed the details of chromosome associations which varied from cell to cell both between and within different accessions. In the germplasm lines studied, a lot of variability with respect to chromosomal associations within and between different accessions was observed, five different types of associations in *V. unguiculata* cv.gr. *sesquipedalis* cultigroup accession, only four types of associations in cultigroup *V. unguiculata* cv.gr. *cylindrical* accession. Six types of associations observed in *unguiculata* cultigroup accession with arrow shaped leaves and four types observed in *unguiculata* cultigroup accession with normal leaves.

The pooled data including 60 cells involving 1320 chromosomes showed that maximum i.e. 25% cells were associated as 11 bivalents followed by 9II + 4I and 1IV + 8II + 2I associations which were visualized in 20% cells each, respectively. Chromosomal associations 1IV + 7II + 4I and 10 II+ 2 I was observed in 15% and 16.66% cells respectively. The minimum association per cell was observed to be 2 IV + 7 II and was visualized in 3.33% cells. Table 4.16 shows the types of chromosomal associations in cowpea accessions. Configurations of more than 4 chromosomes have not

been observed, indicating that there is little if any role of gross structural changes in the evolution of different species. However, the occurrence of multivalent/univalent configurations in meiotic system is an indicator of hybridity involved in the origin of different cultigroups. Table 4.17 shows pooled chromosomal associations.

Table 4.7 Percent Pollen fertility of *Vigna unguiculata* germplasm lines

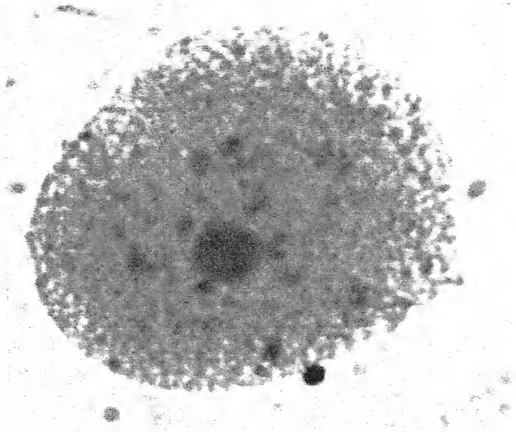
Sl. No.	Accession no	cultigroup	Percent fertile pollens (%)	Pollen fertility ratio (Fertile: sterile)
1	EC 548999	*unguiculata*	92	11:1
2	EC 548878	*sesquipedalis*	90	9:1
3	HY 6P 52-10	*unguiculata*	94	34: 2
4	EC 24102-1	*unguiculata*	86	12: 2
5	EC 548875	*sesquipedalis*	88	14 : 2
6	EC 244236	*unguiculata*	93	13 : 1
7	IL- 1063	*unguiculata*	87	13 : 2
8	EC 548851	*unguiculata*	92	12 : 1
9	IL-160-B	*unguiculata*	88	14 : 2
10	IL 3178	*unguiculata*	92	12 : 1
11	IL-390	*unguiculata*	93	13 : 1
12	RAJL-16	*unguiculata*	88	14: 2
13	IC 438864	*cylindrical*	92	12 : 1
14	IC 438865	*sesquipedalis*	90	18 : 2
15	RAJ-2	*catjang*	90	9 : 1
16	IL-2000-184	*unguiculata*	86	12: 2
17	NP-3-14-A	*unguiculata*	92	11: 1
18	IL-1177	*unguiculata*	92	11 :1
19	EC 240884	*unguiculata*	87	13 : 2
20	IL-99-34	*unguiculata*	89	8 : 1
21	EC 548850	*unguiculata*	87	13 : 2
22	EC 240564	*unguiculata*	88	14 : 2
23	EC 548861	*cylindrical*	93	13 : 1
24	NP-3-14-B	*unguiculata*	80	8 : 2
25	IL-156	*unguiculata*	92	11 : 1
26	RAJL-2	*unguiculata*	83	10 : 2
27	IL-99-72	*unguiculata*	80	4: 1
28	IL-1170-A	*unguiculata*	87	13 : 2
29	IVM-1	*unguiculata*	75	9 : 3
30	IL-3152-1	*unguiculata*	83	10 : 2
31	EC 548864	*pubescence*	88	15 : 2
32	EC 548865	*pubescence*	93	14 : 1
33	IL-131	*unguiculata*	88	14:2
34	EC 548873	*sesquipedalis*	96	23 : 1
35	EC 548866	*sesquipedalis*	94	31: 2
36	EC 548867	*sesquipedalis*	95	21 : 1

Table 4.8 Types of chromosomal associations in *Vigna unguiculata* accessions

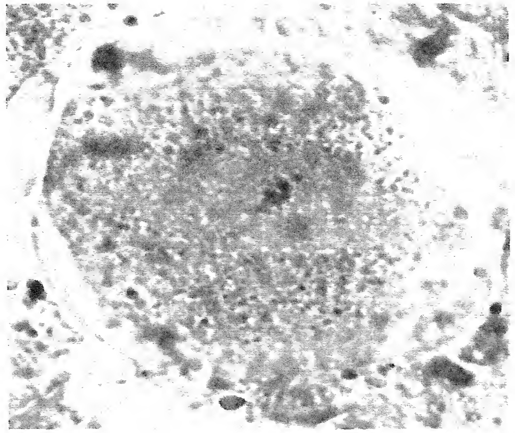
Cultigroups/line	Number of cells	Percent cells	Associations	Chromosomal associations range
***sesquipedalis* EC 548875**	1	6.66	2 IV + 7 II	IV 0-2, II 7-11, I 0-4
	2	13.33	9II + 4I	
	4	26.66	1IV + 8II+ 2I	
	6	40.00	1IV + 7II + 4I	
	2	13.33	11 II	
	Total = 15	Average association: 8.06 II + 0.8 IV + 2.67 I		
***cylindrical* IC 438864**	6	40.00	11 II	IV 0-1, II 8-11, I 0-4
	3	20.00	10 II + 2I	
	2	13.33	1IV + 8 II + 2I	
	4	26.66	9 II + 4I	
	Total = 15	Average association: 9.87 II + 0.13 IV + 1.73 I		
***unguiculata* IL-1177**	1	6.66	1 IV + 8II + 2I	IV 0-1, II 8-11, I 0-4
	4	26.66	11 II	
	6	40.00	10 II + 2I	
	4	26.66	9II + 4I	
	Total =15	Average association: 9.87 II + 0.07 IV + 2.00 I		
***unguiculata* EC 548999**	5	33.33	1 IV + 8II + 2I	IV 0-2, II 7-11, I 0-4
	2	13.33	9II + 4I	
	3	20.00	11 II	
	1	6.66	10 II + 2I	
	1	6.66	2 IV + 7 II	
	3	20.00	1IV + 7II + 4I	
	Total =15	Average association: 8.6 II + 0.7 IV + 2.13 I		

Table 4.9 Pooled chromosomal associations

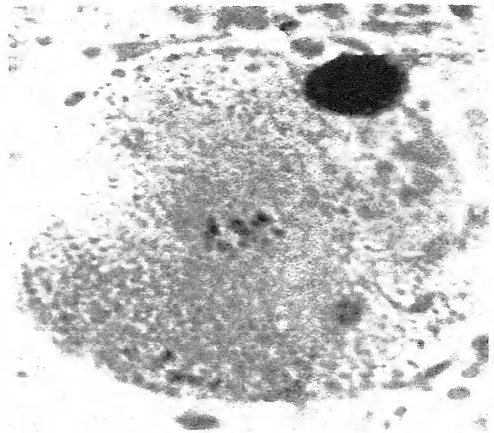
Sl. No.	Associations	Number of cells	Percent cells
1	2 IV +7II	2	3.33
2	9II + 4I	12	20.00
3	1 IV + 8II + 2I	12	20.00
4	1IV + 7II + 4I	9	15.00
5	11 II	15	25.00
6	10 II + 2I	10	16.66
		Total = 60	



Diakinesis IL-1177



Metaphase IL-1177



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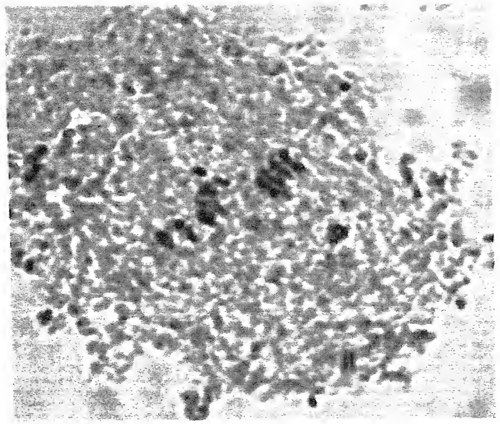

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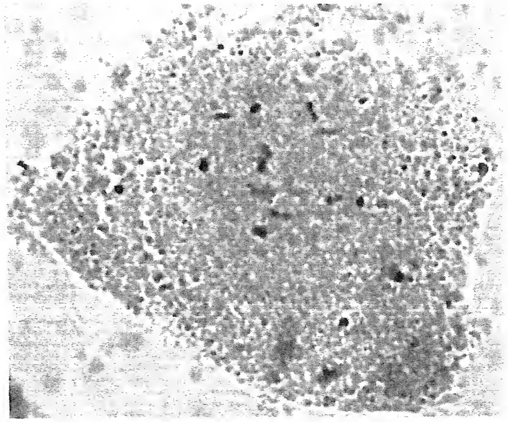

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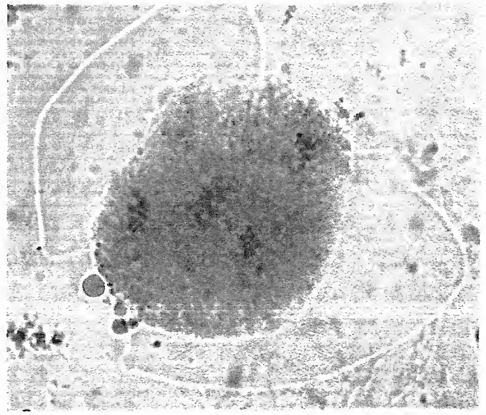
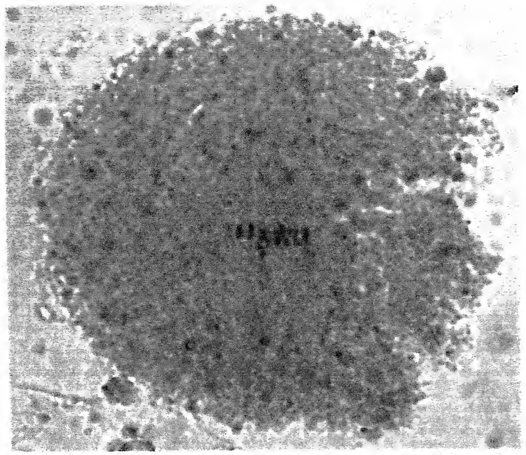
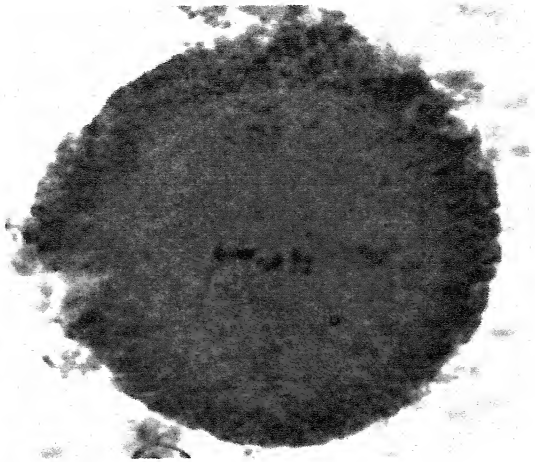


Telophase IL 1177

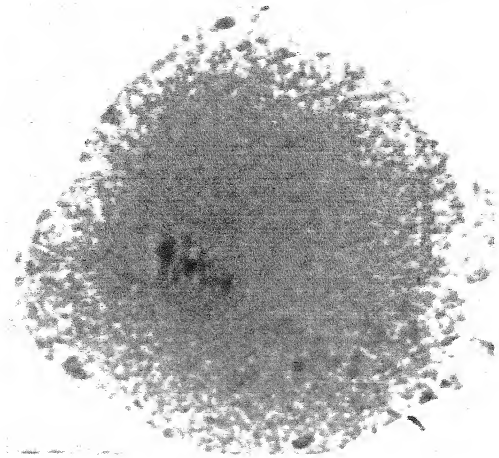
Plate 4.1 Meiotic chromosomal associations and stages of IL-1177 (*V. unguiculata* cv.gr. *unguiculata*)



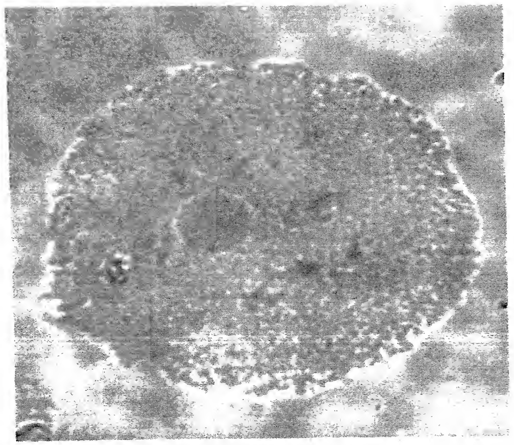
Metaphase plate, EC 548999



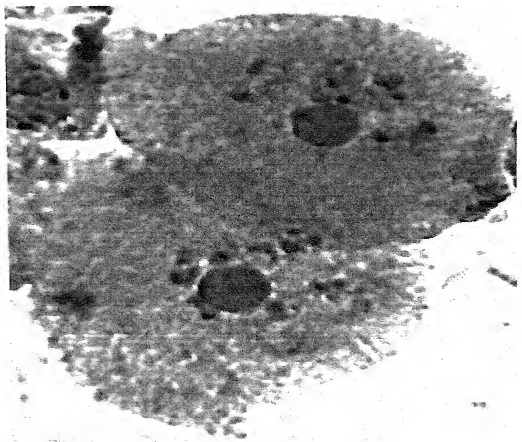
Spindle, EC548999



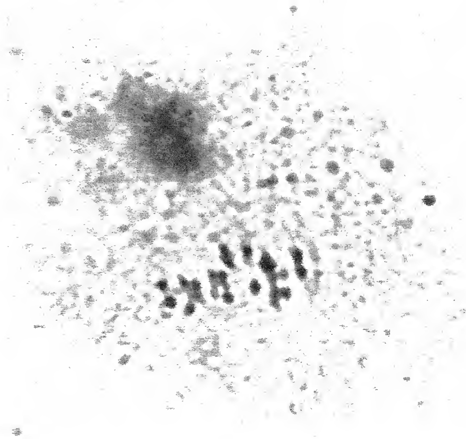
Metaphase EC548999



Diakinesis EC 548875

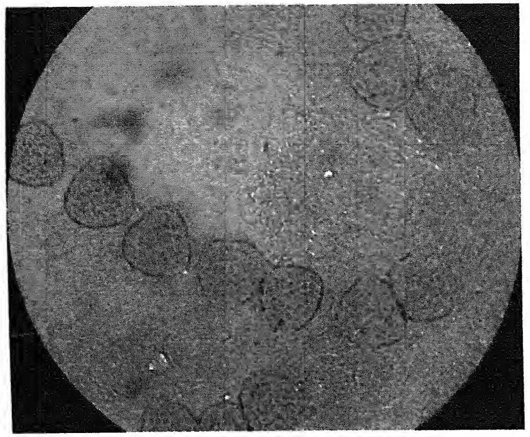


Diakinesis EC548875

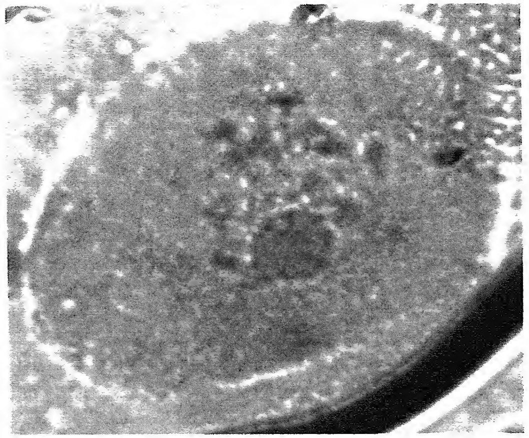


Metaphase EC548875

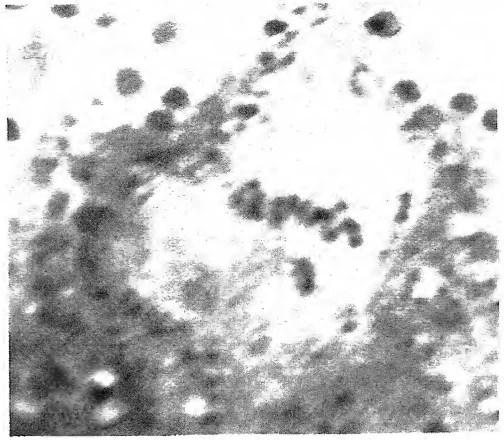
Plate 4.2 Meiotic chromosomal associations and stages of EC548999 (*V. unguiculata* cv.gr. *unguiculata*) and EC 548875 (*V. unguiculata* cv.gr. *sesquipedalis*)



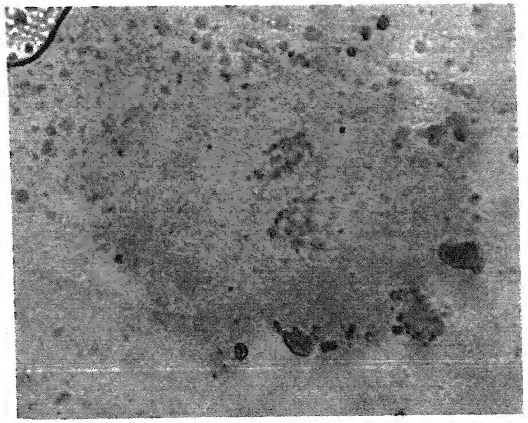
Pollens EC548875



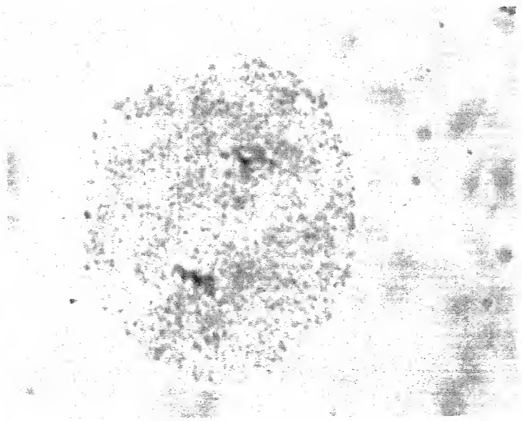
Diakinesis IC 438864



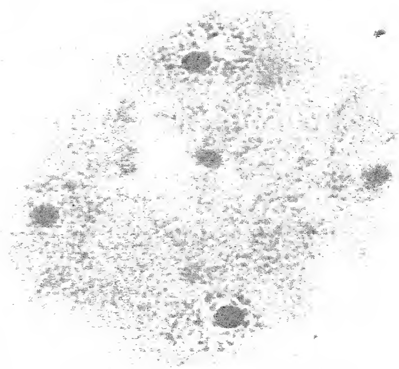
Metaphase IC 438864



Anaphase IC 438864



Anaphase spindle IC 438864



Telophase IC 438864

Plate 4.3 Pollens of EC548875 (*V. unguiculata* cv.gr. *sesquipedalis*) and meiotic chromosomal associations and stages of IC 438864 (*V. unguiculata* cv.gr. *cylindrical*)

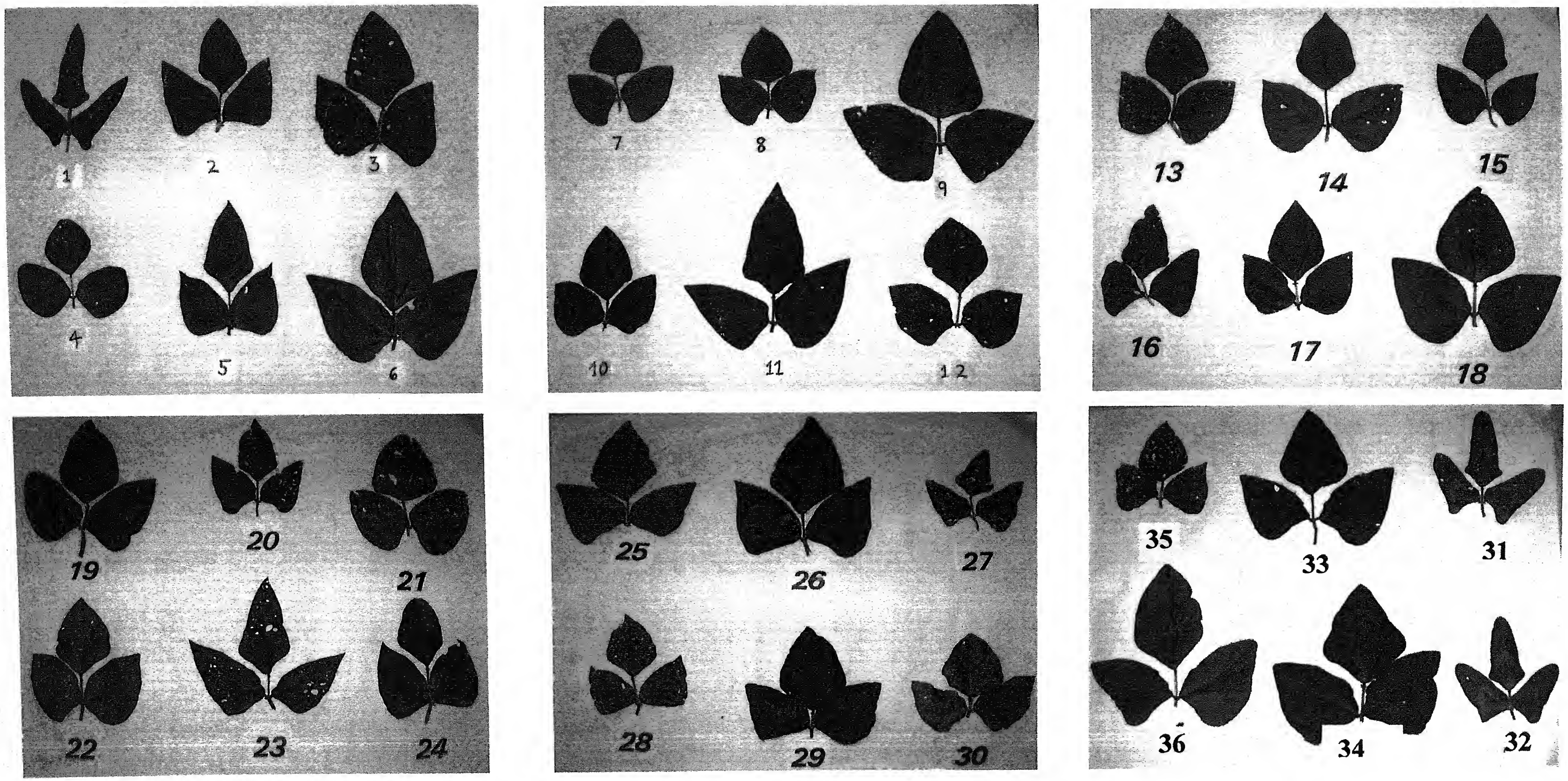


Plate 4.4 Leaves of thirty six *V. unguiculata* germplasm lines taken for bio-chemical studies

4.6 Biochemical characterization

4.6.1 Isozyme profiles of selected germplasm lines

The isozyme analysis of thirty six lines was performed for Esterase, poly phenol oxidase and Sodium dodecyl sulphate for biochemical characterization. The total thirty six lines included six of cultigroup *V. unguiculata* cv.gr. *sesquipedalis,* three of *V. unguiculata* cv.gr. *cylindrical* or *V. unguiculata* cv.gr. *catjang* two of *V. unguiculata* cv.gr. *pubescence*, and twenty five of *V. unguiculata cv.gr unguiculata*. No cultigroup specific bands were observed but different lines were characterized.

4.6.1.1 Esterase

Esterase banding pattern showed presence of ten bands of Rm values 0.01 to 0.52 (table). Eight bands were found to be polymorphic except bands 3 & 7 which were present in higher frequency being recorded in all the 36 genotypes. Band 4 was prominent in the accession EC 548850 of *V. unguiculata* cv.gr. *unguiculata.* Band number 9 was prominent in all genotypes except EC 548999 of cultigroup *V. unguiculata* cv.gr. *unguiculata.* The difference in intensity of the bands indicates quantitative variation for this enzyme.

Vigna unguiculata cv.gr. ***sesquipedalis***

Bands 2, 3, 5, 7, 8, 9 and 10 were observed in all six accessions of this cultigroup. Band 1 was found only in accession EC 548867, band 4 and 6 were absent in accession EC 548875.

Vigna unguiculata cv.gr. *cylindrical* or *Vigna unguiculata* cv.gr. *catjang*

Bands 3, 4, 5, 7, 8, 9, 10 were present and band 1 was absent in both the accessions of this cultigroup. Band 2 was present in IC 438864 and absent in EC548861 whereas band 6 was present in EC548861 and absent in IC 438864.

Bands 3, 4, 5, 7, 9 and 10 were present and 1, 2, 6 and 8 were absent in RAJ-2 line of this cultigroup.

Vigna unguiculata cv.gr. *pubescence*

Bands 2, 3, 6, 7 and 9 were present and bands 1, 4, 5, 8 and 10 were absent in both accessions of this cultigroup.

Vigna unguiculata cv.gr. *unguiculata*

Bands 3, 5, 7 and 9 were present in all the lines of this cultigroup and band 1 was absent in all the lines of this cultigroup. Band 2 was present in all lines except EC 548999, IL 1063, IL-3178, IL-390, RAJL-16 and RAJL-2.

Band 4 was present in all the lines except of this cultigroup except EC 548999, HY6p 52-10, EC 244236, EC548851, IL-1063, RAJL-16, IL-3178 and IL 390. Band 6 was also present in all lines except EC 244236, EC548851, Il-160-B, RAJL-16, IL-99-34 and EC548850. Band 10 was present in all lines except IL-1063, EC548851 and EC548999.

4.6.1.2 Poly phenol oxidase

The banding pattern indicated diversity among the lines. Banding pattern showed presence of 8 bands of Rm values 0.02 to 0.40. Three bands were found to be polymorphic. Bands numbers 1, 2 and 3 were present in higher frequency being recorded in all the 36 lines.

Vigna unguiculata cv.gr. *sesquipedalis*

Bands 1, 2 and 3 were present in all the six accessions of *V. unguiculata* cv.gr. *sesquipedalis.* Band 4 was present in all the accessions of *V. unguiculata* cv.gr. *sesquipedalis* except EC 548878. Band 5 was absent in all the accessions of *V. unguiculata* cv.gr. *sesquipedalis* and band 6 was present only in IC-438865. Band 7 and 8 were present in IC-438865, EC-548873, EC-548866, EC-548867 and absent in EC-548878 and EC-548875.

Vigna unguiculata cv.gr. *cylindrical* or *Vigna unguiculata* cv.gr. *catjang*

Band 6 was present in IC 438864 but absent in EC-548861 accessions of the cultigroup *V. unguiculata* cv.gr. *cylindrical.* PPO isozyme Profile of RAJ-2 line of this cultigroup was similar to PPO isozyme profile of accessions of *V. unguiculata* cv.gr. *pubescence.*

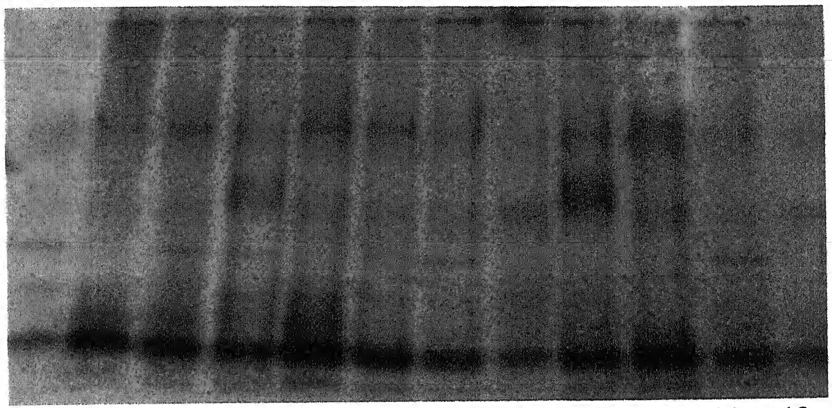
Vigna unguiculata cv.gr. *pubescence*

Both accessions of this cultigroup had similar PPO isozyme profile i.e. bands 1, 2, 3, 4, and 7 were present in both and bands 5, 6 and 8 were absent in both accessions.

Vigna unguiculata cv.gr. *unguiculata*

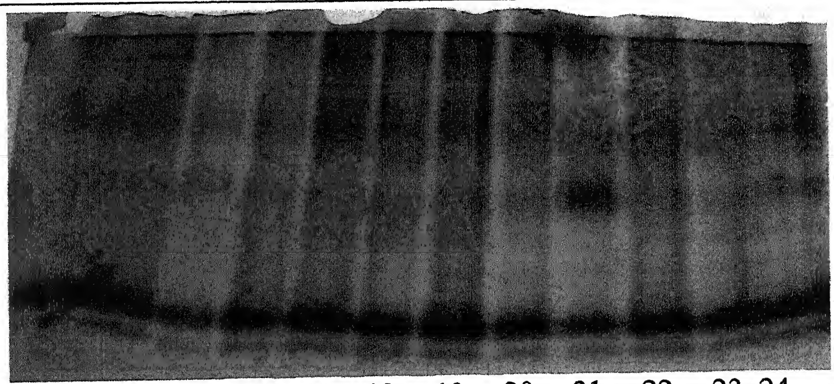
Band 1, 2 and 3 were present in all the twenty five accessions. Band 4 was present in all the accessions except EC-548999 and EC –548851. Band 5 was present in IL-2000-184, IL-1177 and EC-548850 and absent in rest of the lines of *Vigna unguiculata* cv.gr. *unguiculata.*.Band 7 was present in RAJL-16, IL-2000, IL-1177, EC-240889, IL-99-34, EC-548850, EC-240564, NP-3-14-B, IL-156, RAJL-2, IL-99-72, IL-1170-A, ILM-1, IL-3152-1, IL-131 and absent in rest of the lines of *Vigna unguiculata* cv.gr. *unguiculata.*

Band 8 was present in all the lines except EC-548999, EC-548851, IL-160-B, IL-3178, IL-390 & RAJL-16.



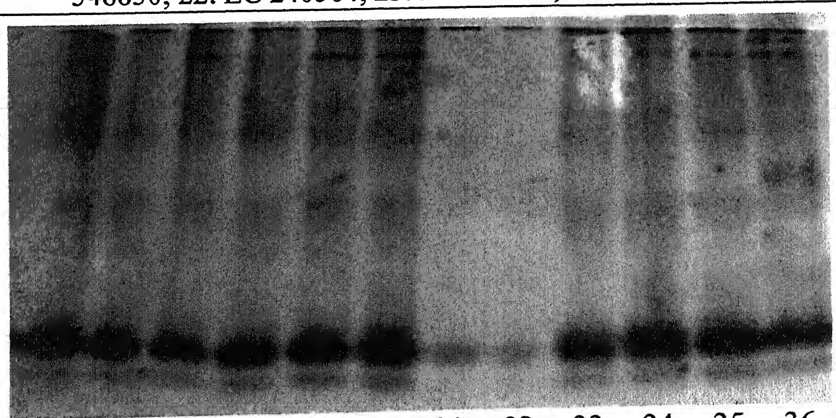
1 2 3 4 5 6 7 8 9 10 11 12

Esterase isozyme profile of germplasm lines 1: EC 548999; 2: EC 548878; 3: Hy 6p 52-10; 4: EC 24102-1; 5: EC 548875; 6: EC 244236; 7: IL- 1063; 8: EC 548851; 9: IL-160-B; 10: IL 3178; 11: IL-390; 12: RAJL-16



13 14 15 16 17 18 19 20 21 22 23 24

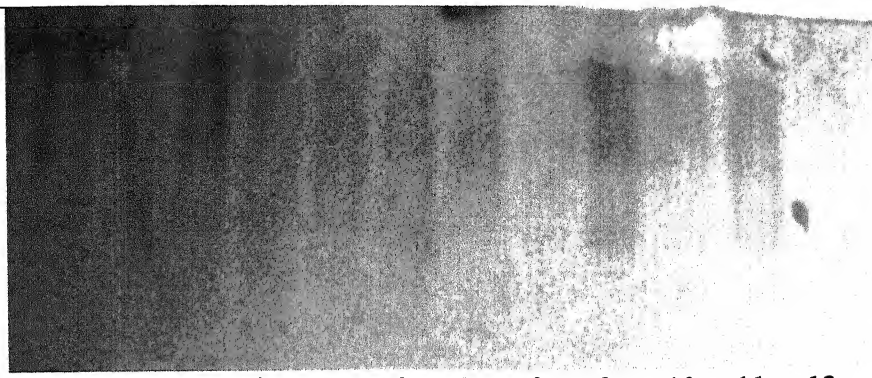
Esterase isozyme profile of germplasm lines 13: IC 438864; 14: IC 438865; 15: RAJ-2; 16: IL-2000-184; 17: NP-3-14-A; 18: IL-1177; 19: EC 240884; 20: IL-99-34; 21: EC 548850; 22: EC 240564; 23: EC 548861; 24: NP-3-14-B



25 26 27 28 29 30 31 32 33 34 35 36

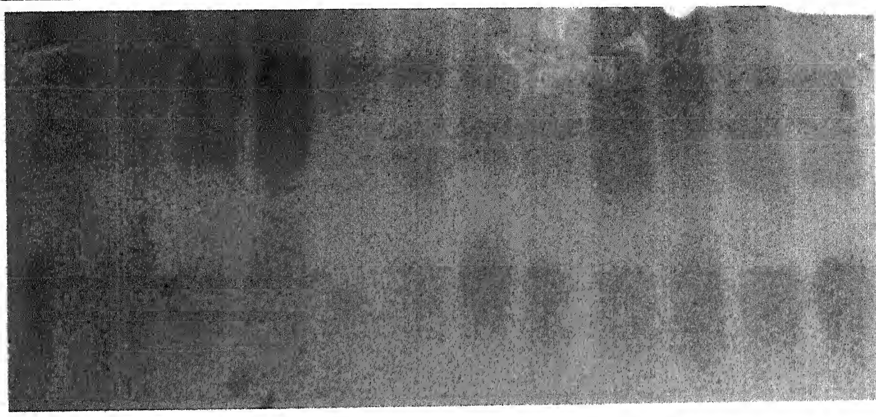
Esterase isozyme profile of germplasm lines 25: IL-156; 26: RAJL-2; 27: IL-99-72; 28: IL-1170-A; 29: IVM-1; 30: IL-3152-1; 31: EC 548864; 32: EC 548865; 33: IL-131; 34: EC 548873; 35: EC 548866; 36: EC 548867

Plate 4.5 Esterase Isozyme profile of thirty six *V. unguiculata* lines taken for biochemical tests



1 2 3 4 5 6 7 8 9 10 11 12

Poly phenol oxidase isozyme profile of germplasm lines 1: EC 548999; 2: EC 548878; 3: Hy 6p 52-10; 4: EC 24102-1; 5: EC 548875; 6: EC 244236; 7: IL- 1063; 8: EC 548851; 9: IL-160-B; 10: IL 3178; 11: IL-390; 12: RAJL-16



13 14 15 16 17 18 19 20 21 22 23 24

Poly phenol oxidase isozyme profile of germplasm lines 13: IC 438864; 14: IC 438865; 15: RAJ-2; 16: IL-2000-184; 17: NP-3-14-A; 18: IL-1177; 19: EC 240884; 20: IL-99-34; 21: EC 548850; 22: EC 240564; 23: EC 548861; 24: NP-3-14-B

25 26 27 28 29 30 31 32 33 34 35 36

Poly phenol oxidase isozyme profile of germplasm lines 25: IL-156; 26: RAJL-2; 27: IL-99-72; 28: IL-1170-A; 29: IVM-1; 30: IL-3152-1; 31: EC 548864; 32: EC 548865; 33: IL-131; 34: EC 548873; 35: EC 548866; 36: EC 548867

Plate 4.6 Poly phenol oxidase Isozyme profile of thirty six *V. unguiculata* lines taken for biochemical tests

4.6.1.3 Peroxidase

The banding pattern of peroxidase revealed nine bands in total of Rm values 0.01 to 0.35. Bands number 1, 2, 3 and 5 were the most frequent. Band 1, 2, 3, 4, 5 and 9 were prominent in Hy6p 52-10 line of cultigroup, *unguiculata*. Band 3 was also prominent in genotype IL-156 of cultigroup, *unguiculata* showing differential activity.

Vigna unguiculata cv.gr. *sesquipedalis*

Band 1 and 2 were present in all the accessions except EC-548878. Band 3 was present in all the accession except EC-548878 and IC-438865. Band 4 was absent in all the accessions. Band 5 was present in EC-548873, EC-548866 and EC-548867 and absent in EC 548878, EC-548875 and IC-435865.

Band 6 was present only in EC-548866 and absent in rest of the lines. Band 7 and 8 were present only in EC-548875 and absent in rest of the lines. Band 9 was present in EC-548878 and EC-548875 and absent in rest of the lines.

Vigna unguiculata cv.gr. *cylindrical* or *Vigna unguiculata* cv.gr. *catjang*

Both lines had similar peroxidase isozyme profile except band 2 which was present in EC-548861 and absent in IC-438864. Only band 1 and 2 were present in RAJ-2 line of this cultigroup.

Vigna unguiculata cv.gr. *pubescence*

Both lines had similar peroxidase isozyme profile except band 6 that was present in EC-548865 and absent in accession EC-548864.

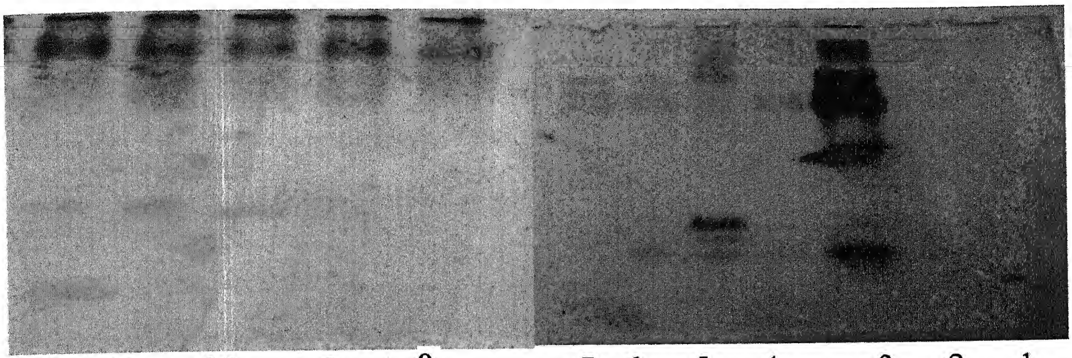
Vigna unguiculata cv.gr. *unguiculata*

Accession EC-548999 did not show any peroxidase band. Band 1 was present in all the lines except EC-24102-1 and IL-1177. Band 2 was present in all the lines except EC-24102-1. Band 3 was present in all the lines except EC-24102-1, IL-2000-184, NP-3-14-A, IL-1177, EC-240884, IL-99-34, EC-548850, EC-240564, NP-3-14-B.

Band 5 was present in HY6P-52-10, IL-1063, IL2000-184, IL-156, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1 and IL-131. Band 6 was present only in HY6P52-10 and IL-2000-184 and absent in rest of the lines of *Vigna unguiculata* cv.gr. *unguiculata*.

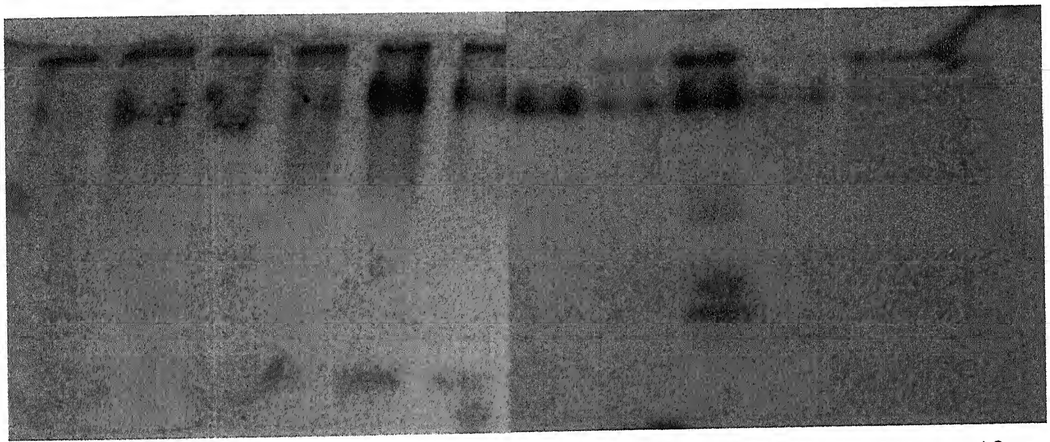
Band 7 was present only in HY6P52-10, EC-244236, IL-3178, IL-390 and IL-2000-184 and absent in rest of the lines. Band 8 was present only in EC 244236 and IL-2000-184 and absent in rest of the lines of *Vigna unguiculata* cv.gr. *unguiculata*.

Band 9 was present in HY6P-52-10, EC-24102-1, EC-244236, IL-99-72 and IL-3152-1.



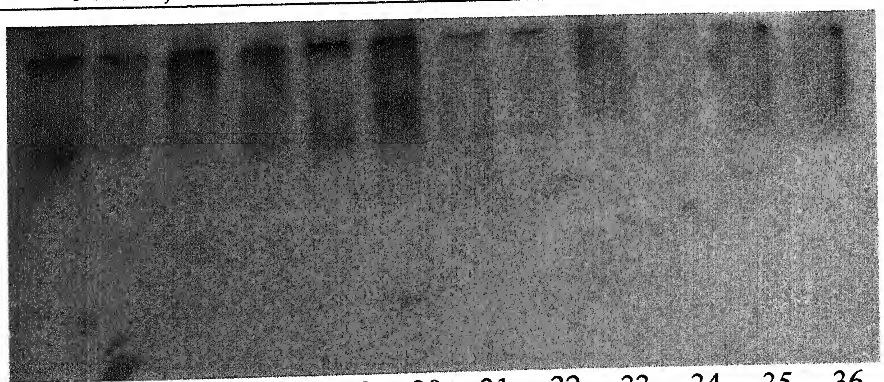
12 11 10 9 8 7 6 5 4 3 2 1

Peroxidase isozyme profile of germplasm lines 1: EC 548999; 2: EC 548878; 3: Hy 6p 52-10; 4: EC 24102-1; 5: EC 548875; 6: EC 244236; 7: IL- 1063; 8: EC 548851; 9: IL-160-B; 10: IL 3178; 11: IL-390; 12: RAJL-16



24 23 22 21 20 19 18 17 16 15 14 13

Peroxidase isozyme profile of germplasm lines 13: IC 438864; 14: IC 438865; 15: RAJ-2; 16: IL-2000-184; 17: NP-3-14-A; 18: IL-1177; 19: EC 240884; 20: IL-99-34; 21: EC 548850; 22: EC 240564; 23: EC 548861; 24: NP-3-14-B



25 26 27 28 29 30 31 32 33 34 35 36

Peroxidase isozyme profile of germplasm lines 25: IL-156; 26: RAJL-2; 27: IL-99-72; 28: IL-1170-A; 29: IVM-1; 30: IL-3152-1; 31: EC 548864; 32: EC 548865; 33: IL-131; 34: EC 548873; 35: EC 548866; 36: EC 548867

Plate 4.7 Peroxidase Isozyme profile of thirty six *V. unguiculata* lines taken for biochemical tests

4.6.1.4 Sodium dodecyl sulphate

The banding pattern of SDS revealed 9 bands of Rm values 0.01 – 0.56. The SDS banding pattern revealed polymorphism for all the 9 bands and diversity was observed.

Vigna unguiculata cv.gr. *sesquipedalis*

SDS Profile of accessions IC-438865, EC-548873, EC-548866 and EC-548867 were similar with all the nine bands present.

Bands 3, 4, 5 and 9 were present in accessions i.e. EC 548878 and EC 548875 whereas bands 2, 6 and 7 were absent in these accessions. However, bands 1 and 8 were present in EC 548878 and absent in EC 548875.

Vigna unguiculata cv. gr. *cylindrical*

Band 5 was present in both accessions, IC-438864 and EC-548861. Bands 3, 6, 7, 8 and 9 were present in IC-438864 and absent in EC-548861. Bands 1, 2 and 4 were absent in both.

Vigna unguiculata cv.gr. *pubescence* and *Vigna unguiculata* cv.gr. *catjang*

The SDS profiles were similar with all the bands present in the accessions of these cultigroups i.e. EC548864, EC548865 and RAJ-2.

Vigna unguiculata cv.gr. *unguiculata*

Band 1 was present in all the lines except EC 548999, RAJL-16, IL-2000-184 and NP-3-14-A. The SDS Profile of 11 lines viz. EC 244236, IL-1063, Il-160-B, EC-240884, IL-156, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1 and IL-131 showed all the nine bands.

Band 2 was present in all lines except RAJL-16, IL-2000-184, IL-1177, NP-3-14-A, IL-99-34 and EC-548850. Band 3 was present in all lines except IL-390, IL-2000-184. Band 4 was present in all lines except IL-390, IL-2000-184, NP-3-14-A, IL-1177, IL-99-34. Band 5 was present in all lines except IL-99-34 and EC-548850.

Band 6 was present in EC 244236, IL-1063, IL-160-B, EC-240884, IL-156, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1 IL-131, IL-2000-184 and EC-240564 and absent in rest of the lines of cultigroup *unguiculata*. Band 7 was present in EC 244236, IL-1063, Il-160-B, EC-240884, IL-156, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1 and IL-131, HY6P-52-10, RAJL-16, IL-2000-184 and EC-548850 and absent in rest of the lines of cultigroup *unguiculata*.

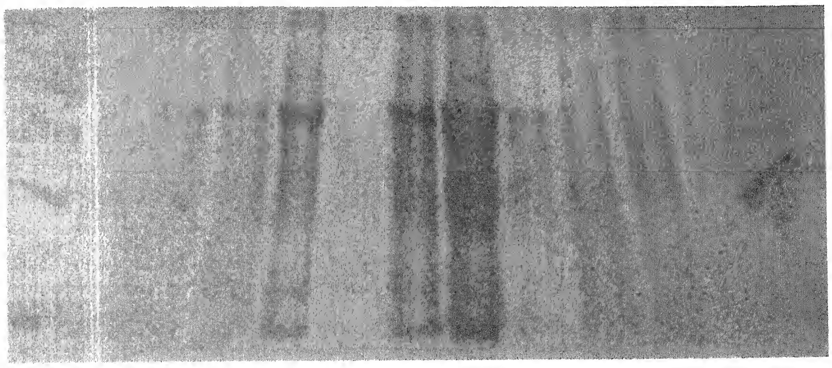
Band 8 was present in EC 244236, IL-1063, IL-160-B, EC-240884, IL-156, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1 and IL-131, HY6P52-10, EC24102-1,

RAJL-16, IL-2000-184, NP-3-14-B IL-2000-184 and EC-240564 and absent in rest of the lines of *Vigna unguiculata* cv. gr. *unguiculata*.

Band 9 was present in all the lines of *Vigna unguiculata* cv.gr. *unguiculata* except NP-3-14-A, IL-1177, IL-99-34, EL-548850 and NP-3-14-B. All the enzyme system-banding patterns studied were found to be polymorphic. This indicates presence of considerable amount of genetic variability among the genotypes. Thus the above lines are characterized at biochemical level by better tools which establish uniqueness and identities of individual lines for further utilization. Table 4.18 shows relative mobility values of isozyme profiles of evaluated lines

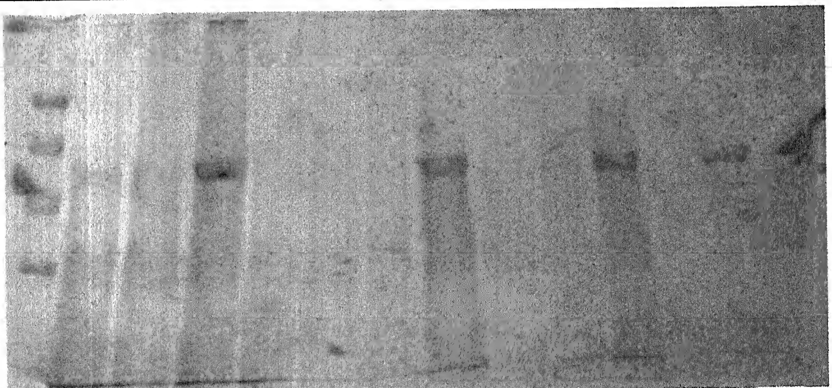
Table 4.10 Relative mobility values of isozyme profiles of evaluated lines

Sl. No.	Esterase	PPO	Peroxidase	SDS
1	0.01	0.02	0.01	0.01
2	0.04	0.05	0.03	0.02
3	0.05	0.13	0.04	0.03
4	0.08	0.18	0.05	0.05
5	0.09	0.21	0.06	0.08
6	0.18	0.29	0.09	0.14
7	0.20	0.36	0.19	0.35
8	0.31	0.40	0.20	0.48
9	0.45		0.35	0.56
10	0.52			



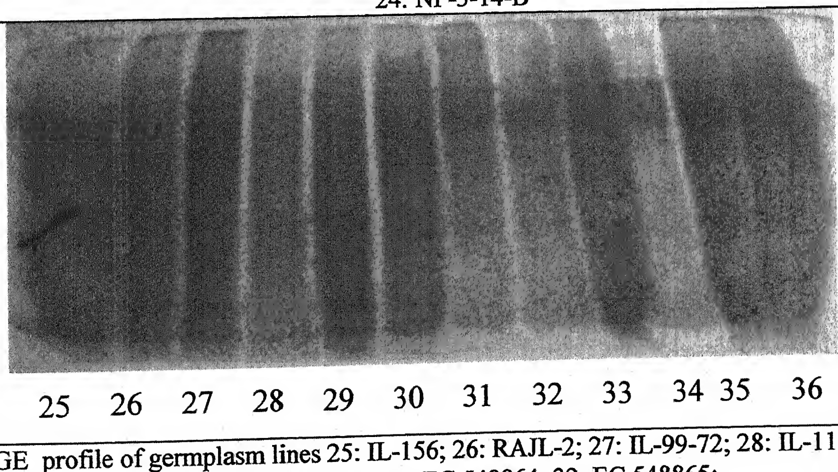
1 2 3 4 5 6 7 8 9 10 11 12

SDS PAGE profile of germplasm lines 1: EC 548999; 2: EC 548878; 3: Hy 6p 52-10; 4: EC 24102-1; 5: EC 548875; 6: EC 244236; 7: IL- 1063; 8: EC 548851; 9: IL-160-B; 10: IL 3178; 11: IL-390; 12: RAJL-16



13 14 15 16 17 18 19 20 21 22 23 24

SDS PAGE profile of germplasm lines 13: IC 438864; 14: IC 438865; 15: RAJ-2; 16: IL-2000-184; 17: NP-3-14-A; 18: IL-1177; 19: EC 240884; 20: IL-99-34; 21: EC 548850; 22: EC 240564; 23: EC 548861; 24: NP-3-14-B



25 26 27 28 29 30 31 32 33 34 35 36

SDS PAGE profile of germplasm lines 25: IL-156; 26: RAJL-2; 27: IL-99-72; 28: IL-1170-A; 29: IVM-1; 30: IL-3152-1; 31: EC 548864; 32: EC 548865; 33: IL-131; 34: EC 548873; 35: EC 548866; 36: EC 548867

Plate 4.8 SDS Isozyme profile of thirty six *V. unguiculata* lines taken for biochemical tests

4.6.2 Chemical seed tests

Six chemical ripe seed tests were performed on 36 germplasm lines for determining distinctive uniqueness of the lines.

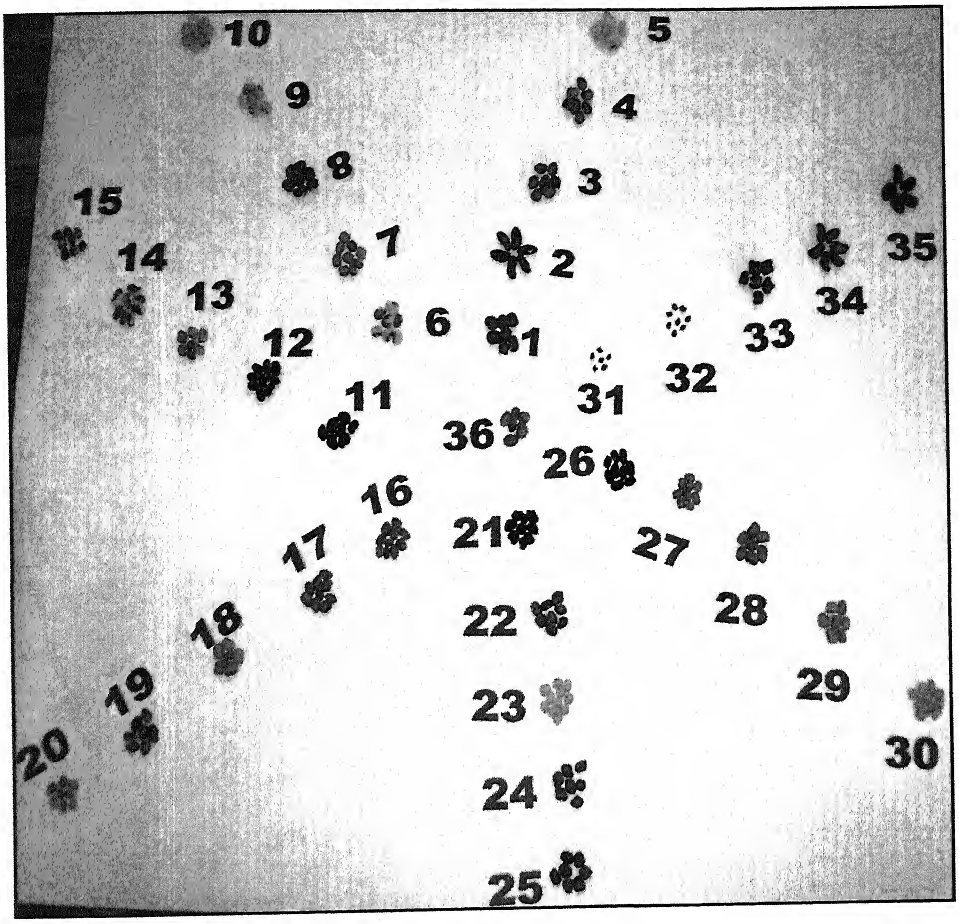


Plate 4.9 Seeds of thirty six *V. unguiculata* lines of germplasm taken for biochemical tests

4.6.2.1 Peroxidase test

Lines EC-548875, IL-1063, EC-548851, IL-3178, RAJL-16, IC-438865, IL-2000-184, NP-3-14-A, IL-1177, IL-99-34, NP-3-14-B, IL-156, RAJL-2, IL-1170-A, EC-548873 showed a positive reaction with red colour change.

Lines EC-548999, EC-548878, HY6P52-10, EC-24102-1, EC244236, IL-160-B, IL-390, IC-438864, RAJL2, EC-240884, EC-548850, EC-240564, EC-548861, IL-99-72, IVM-1, IL-3152-1, EC-548864, EC-548865, IL-131, EC548866 and EC 548867 showed a negative reaction with no colour change.

4.6.2.2 NaOH test

Lines EC548999, EC548878, HY6P52-10, EC-24102-1, EC-244236, IL-1063, EC-548851, IL-3178, IL-390, RAJ-2, NP-3-14-B, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1, EC548864 showed positive reaction with red colour change.

Lines EC548875, IL-160-B, RAJL-16, IC-438864, IC-438865, IL-2000-184, IL-99-34, EC-548850, EC-240564, IL-156, EC-548864, EC-548865, IL-131, EC-548873, EC-548866, EC-548867 showed a negative reaction with no colour change.

4.6.2.3 KOH bleach test

Accession EC244236 showed positive reaction i.e. bleached seed coat colour whereas rest all the lines showed a negative reaction with no colour change.

4.6.2.4 Phenol colour test

Accession EC-24102-1 showed black tip and line RAJ-2 showed black colour change of seed coat. Rest other lines did not show any colour change.

4.6.2.5 Fluorescence test

All the lines showed florescence except lines NP-3-14-A, IL-156, RAJL-2, IL-99-72, IL-1170-A, IL-3152-1, EC-548873, EC-548866 and EC548867.

4.6.2.6 GA_3 growth test

Lines EC548999, HY6P-52-10, IL-1063, IL-160-B, IL-31-78, RAJ-2, IL-2000-184, NP-3-14-A, IL-1177, EC548861, NP-3-14-B, RAJL-2, EC-548864, EC548865 and IL-131 showed high response for both dry weight and seedling weight. Whereas lines EC-548878, EC-24102-1, EC-548875, EC-244236, EC-548851, IL-390, RAJL-16, IC438864, IC438865, IL-99-72, EC-548873, EC-548866 and EC-548867 showed low response for both dry weight and seedling weight.

Lines EC-240884, IL-99-34, EC-548850, IL-1170-A and IVM-1 showed a high response for only seedling weight. Lines EC 240564 and IL-3152-1 showed high response for dry weight by low response of seedling weight. Line IL-156 showed a low response for seedling weight.

Table 4.19 shows the biochemical characterization of cowpea germplasm whose biochemical study was performed.

Table 4.11 Biochemical characterization of *Vigna unguiculata* germplasm

Sl. No	Accession	CGC	Origin	Seed tests				Isozymes (Bands present)			
				Peroxidase	NaOH	Fluorescence	GA_3 growth	Peroxidase	PPO	Esterase	SDS PAGE
1	EC 548999	1	Kenya	NC	R	Fl	I	-	1,2,3	3,5,6,7,8,9	2,3,4,5,9
2	EC 548878	3	Taiwan	NC	R	Fl	NC	9	1,2,3,4	2,3,4,5,6,7,8,9,10	1,3,4,5,8,9
3	Hy 6p 52-10	1	India	NC	R	Fl	I	1,2,3,4,5,6,7,9	1,2,3,4,8	2,3,5,6,7,8,9,10	1,2,3,4,5,7,8,9
4	EC 24102-1	1	-	NC	R	Fl	NC	4,9	1,2,3,4,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,8,9
5	EC 548875	3	Thailand	R	NC	Fl	NC	1,2,3, 7,8,9	1,2,3,4,8	2,3,5,7,8,9,10	3,4,5,9
6	EC 244236	1	-	NC	R	Fl	NC	1,2,3,4,5,9	1,2,3,4,8	2,3,5,7,8,9,10	1,2,3,4,5,6,7,8,9
7	IL- 1063	1	India	R	R	Fl	I	1,2,3,4,5	1,2,3,4,8	3,5,6,7,8,9	1,2,3,4,5,6,7,8,9
8	EC 548851	1	Australia	R	R	Fl	NC	1,2,3	1,2,3,	2,3,5,7,8,9	1,2,3,4,5,9
9	IL-160-B	1	India	NC	NC	Fl	I	1,2,3	1,2,3,4	2,3,4,5,7,8,9,10	1,2,3,4,5,6,7,8,9
10	IL 3178	1	India	R	R	Fl	I	1,2,3,7	1,2,3,4	3,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
11	IL-390	1	India	NC	R	Fl	NC	1,2,3,7	1,2,3,4	3,5,6,7,8,9,10	1,2 ,5, ,9
12	RAJL-16	1	NEH	R	NC	Fl	NC	1,2,3,7	1,2,3,4,7	,3,5,7,8,9,10	3,4,5,7,8,9
13	IC 438864	5	India	NC	NC	Fl	NC	1	1,2,3,4,6,7,8	2,3,4,5,7,8,9,10	3,5,6,7,8,9
14	IC 438865	3	India	R	NC	Fl	NC	1,2	1,2,3,46,7,8	2,3,4,5,6,7,8,9,10	1,2,4,5,6,7,8
15	RAJ-2	2	NEH	NC	R	Fl	I	1,2	1,2,3,4,7	3,4,5,7,9,10	1,2,3,4,5,6,7,8,9
16	IL-2000-184	1	India	R	NC	Fl	I	1,2,4,5,6,7,8,9	1,2,3,4,5,6,7,8	2,3,4,5,6,7,8,9,10	5,6,7,8,9
17	NP-3-14-A	1	India	R	R		I	1,2	1,2,3,4,8	2,3,4,5,6,7,8,9,10	3,5
18	IL-1177	1	India	R	R	Fl	I	2,9	1,2,3,4,5,7,8	2,3,4,5,6,7,8,9,10	3,5
19	EC 240884	1	-	NC	R	Fl	I	1,2,9	1,2,3,4,6,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
20	IL-99-34	1	India	R	R	Fl	I	1,2,9	1,2,3,4,7,8	2,3,4,5,7,8,9,10	3
21	EC 548850	1	Australia	NC	NC	Fl	I	1,2	1,2,3,4,5, 7, 8	2,3,4,5,7,8,9,10	3,4,9
22	EC 240564	1	-	NC	NC	Fl	I	1,2	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	2,3,4,5,6,9
23	EC 548861	5	Guatemal	NC	R	Fl	I	1,2	1,2,3,4,7,8	3,4,5,6,7,8,9,10	5
24	NP-3-14-B	1	India	R	R	Fl	I	1,2	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	2,3,4,5, 8,9
25	IL-156	1	India	R	NC	N Fl	NC	1,2,3,5	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
26	RAJL-2	1	NEH	R	R	N Fl	I	1,2,3,5	1,2,3,4,7,8	,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
27	IL-99-72	1	India	NC	R	N Fl	NC	1,2,3,5,9	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
28	IL-1170-A	1	India	R	R	N Fl	I	1,2,3,5	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
29	IVM-1	1	India	NC	R	Fl	I	1,2,3,5	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
30	IL-3152-1	1	India	NC	R	N Fl	I	1,2,3,5,9	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
31	EC 548864	4	Tanzania	NC	NC	Fl	I	1,2,3,5,	1,2,3,4,,8	2,3,5,6,7,9	1,2,3,4,5,6,7,8,9
32	EC 548865	4	Tanzania	NC	NC	Fl	I	1,2,3,5,6	1,2,3,4,7,8	2,3,5,6,7,9	1,2,3,4,5,6,7,8,9
33	IL-131	1	India	NC	NC	Fl	I	1,2,3,5	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
34	EC 548873	3	China	R	NC	N Fl	NC	1,2,3,5	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
35	EC 548866	3	Nepal	NC	NC	Fl	NC	1,2,3,5,6	1,2,3,4,7,8	2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9
36	EC 548867	3	China	NC	NC	Fl	NC	1,2,3,5	1,2,3,4,7,8	1,2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9

CGC: cultivar group codes (Marechal, 1978) 1: *unguiculata;* 2: *catjang;* 3: *sesquipedalis;* 4: *pubescence;* and 5: *cylindrica*; NC: No Change, R: Red colour reaction; Fl: Fluorescent; N Fl: Non fluorescent; I: Increased seedling length and dry weight; PPO: polyphenol oxidase

DISCUSSION

The evaluated cowpea germplasm showed wide variability for forage and seed yield attributes as well as other morphological characters. Out of the 172 lines, including checks and control, maximum lines were found to have medium early plant vigour with plant height ranging from 15 cm to 20 cm at 25 DAS. About 30 per cent lines showed good early plant vigour with plant height more than 20 cm at 25 DAS. On considering the growth habit, maximum (74) lines were of spreading type, six lines were of bushy type and twelve lines were of erect type. The plant height of most (72) of the genotypes was from 136 to 165 cm, however three lines had plant height more than 226 cm. Many genotypes *viz.* IL-99-40; IL-2000-179; IL-2000-183; IL-1053 and IVM had red pigmented stems. The leaves of most of the genotypes were of broad type but few lines (RAJL-4; IL-14177-A; IL-99-98; and IL-99-40) were also having small and narrow leaves. Accession EC240884 had whitish green leaves which could distinguish the accession from other lines. Some lines (UPC-870; and IGFRI-95-1) had dark green leaves that was a prominent characteristic. Accession IL-853 had dark green leaf with red pigmented veins. One more distinguishing characteristic of the leaves was the orientation of leaf blade i.e. either vertical or horizontal. Lines HY- 6P-52-9 and HY-10-36-4 had vertical orientation whereas EC -244310 had leaves curled tip downwards i.e. horizontal orientation. Some lines were having rough leaf surface e.g. NP 3-14-A and IL-181.

The number of days to 50 per cent flowering varied from 45 to 85 days within the germplasm evaluated. Maximum (64) lines had 46 to 55 DAS to 50 per cent flowering. The biomass per plant varied from 106 to 990 g in the germplasm lines evaluated and maximum lines showed biomass per plant in the range of 281- 455 g.

The dry weight per plant varied from 61 to 660 g and maximum number of genotypes showed 61-180 g, dry weight per plant. The leaf stem ratio (both fresh and dry) varied from 0.2 to 1.0 and maximum lines had fresh leaf stem ratio in between 0.6 and 0.7 whereas dry leaf stem ratio was in between 0.5 and 0.6. The number of days to maturity initiation varied from 60 to 120 DAS. Maximum number of lines showed maturity initiation in between 61 to 80 days.

On considering the grain traits, the number of pods varied within the germplasm from 5 to 55 and maximum number of lines showed number of pods in between 6-15 followed by 16-25 number of pods per plant.

The pod length of the entire germplasm varied from 6 to 25 cm and maximum number of lines had pod length ranging from 11 to 15 cm. The pod showed variation in length, width, colour, shape and fleshy ness. The genotypes having broad pods were IL-99-72; IL-1057; IL-153-1; and IL- 4216. Line IL-210 showed very small and thin pods, IL-1050-3 showed thin long pods, IL-622 showed very good pod clusters of dark green colour. Fleshy pods were shown by EC-244249; HY-5P-6S-215; and NP-3-8. Line IL-2000-178 showed very fat pods. Line IL-99-2 showed red pigmented pods. IL-2000-180 showed pods which were red in milky stage. Line IL-131 showed small red pods. Line IL-160 showed light green pods. Line IL-2000-188 showed C- shaped pods which was a unique characteristic. Line IL-182 showed whitish green pods. Number of seeds per pod and per plant varied within the germplasm with maximum genotypes having 13 to 16 seeds per pod. Few lines showed heavy seed set of 21 to 24 seeds per pod and few showed a low seed set of 5 to 8 seeds per pod.

5.1 Clustering pattern of the germplasm

Clustering pattern of the germplasm as a whole was analyzed based on average data of two years. Pooling of the data was done by taking out the average value of the trait recorded for the year 2004-05 and 2005-06. The data thus pooled is shown in Appendix C. Cluster analysis, performed on the pooled data, formed 12 clusters for 20 trait variables. Table 5.1 shows the accessions grouped in different clusters for the pooled data of the years 2004-05 and 2005-06. In this clustering pattern, cluster number 5 was the biggest with 26 lines and cluster number 4 was the smallest with only 1 member.

Table 5.2 shows morphological character's mean and standard deviation for different clusters of the data pooled for the years 2004-05 and 2005-06. The genotypes in cluster number 10 flowered most late with mean value of 50 per cent days to flowering being as 70.50 ± 9.19 days. Earliest flowering lines were grouped in cluster number 3 with minimum mean value of 50 per cent days to flowering being as 46.78 ± 4.71 days.

The lines with maximum total span of days to total flowering were grouped in cluster number 6 with maximum mean value of 93.29 ± 6.08 days and lines with shortest total span of days to total flowering were grouped in cluster number 3 with minimum mean value of 63.22 ± 7.56 days.

The tallest lines were clustered in cluster number 4 with maximum mean value of plant height being as 205.72 ± 0.0 cm and shortest genotypes were clustered in cluster number 8 with minimum mean value of 148.2 ± 3.66 cm.

The highest number of nodes per plant was observed in genotypes of cluster number 4 with a mean value of 27.98 ± 0.0 nodes and lowest number of nodes per plant was observed in genotypes of cluster number 2 with a mean value of 17.72± 2.82 nodes.

The germplasm lines having highest mean value of number of primary branches, (8.58 ± 0.0) were grouped in cluster number 4. Whereas, lines having lowest mean value of number of primary branches (4.07 ± 0.73) were grouped in cluster number 9.

The highest numbers of secondary branches with mean value of 11.67±1.53 were grouped in cluster number 10. The lowest numbers of secondary branches with mean value of 2.32±0.00 were grouped in cluster number 4.

The thick stemmed lines were grouped in cluster number 10 with highest mean value of stem girth 1.69 ± 0.28 cm and thin stemmed lines were grouped in cluster number 7 with lowest mean value of stem girth 0.89 ± 0.10 cm.

More leafy lines were grouped in cluster number 4 with a maximum mean value of 185.29 ± 0.0 leaves per plant and less leafy lines were clubbed in cluster number 7 with minimum mean value 39.87 ± 11.71 leaves per plant.

The longest leaf length having lines were grouped in cluster number 4 having mean value of leaf length as 14.25 ± 0.00 cm and shortest leaf length having lines were grouped in cluster number 5 having mean value of leaf length as 9.36 ± 0.77 cm.

The broadest leaves possessing lines were clubbed in cluster number 1 having maximum mean value of leaf width as 8.67 ± 1.30 cm. Whereas less broader leaves possessing lines were clubbed in cluster number 5 with minimum mean value of leaf width as 5.82±0.70 cm.

Higher fodder yielding lines were grouped in cluster number 10 with maximum mean value of fresh biomass per plant being as 859.33 ±- 119.08 g and dry biomass per

plant being as 580.07±64.26 g. However, low fodder yielding lines were grouped in cluster number 9 with minimum value of fresh biomass per plant being as 237.17±72.00 g and dry biomass per plant being as 115.36 ± 27.67 g.

The heaviest seed bearing lines carrying maximum mean value of 100 seed weight as 16.72±0.0 g were clustered in cluster number 4 and lightest seed bearing lines carrying minimum mean value of 100 seed weight as 11.84±2.46 g were clustered in cluster number 9.

The late maturity initiation was observed in genotypes of cluster number 4 with maximum mean value of days to maturity initiation being as 116.00±0.0 DAS and genotypes with early maturity initiation were clustered in cluster number 3 with a minimum value of days to maturity initiation being as 76.22 ± 8.55 DAS.

The genotypes with maximum span of days to total maturity were clustered in cluster number 6 with a maximum mean value of 138.87 ± 6.22 days and genotypes with less span of pod maturity were clustered in cluster number 9 with a minimum mean value of 120.91 ± 6.01 days.

The lines with higher number of pod clusters were grouped in cluster number 8 with maximum mean value of 15.39 ± 3.99 pods and lines with less number of pod clusters per plant were grouped in cluster number 2 with a minimum mean value 4.76 ± 2.52 pod clusters per plant. The maximum pod bearing lines were grouped in cluster 11 with a mean value of 44.70 ± 5.38 pods per plant and minimum pod bearing lines were grouped in cluster number 10 with a mean value 9.19 ± 4.36 pods per plant.

The longest pod bearing lines were clustered in cluster number 4 with maximum pod length mean value of 18.98±0.0 cm and shortest pod bearing lines were clustered in cluster number 9 with minimum pod length mean value 12.31±2.25 cm.

The highest number of seeds per pod bearing genotypes were grouped in cluster number 4 with a mean value of 20.82 ± 0.00 seeds per pod and lowest seed per pod bearing lines were grouped in cluster number 9 with minimum mean value 11.51 ± 1.92 seeds per pod.

The higher numbers of seeds per plant carrying genotypes were grouped in cluster number 11 with a mean value of 616.21±84.97 seeds per plant and lower numbers of seeds per plant carrying genotypes were grouped in cluster number 2 with a mean value of 139.72 ±77.79 seeds per plant.

Table 5.3 shows the distance between centroids of twelve clusters taken for the pooled data of the year 2004-05 and 2005-06. The maximum distance (11.781) between cluster centroids was between clusters 7 and 10; followed by distance 11.589 between clusters 9 and 10; and distance 11.054 between clusters 10 and 11. Table 5.4 shows average distances of cluster members from cluster centroids. Maximum average distance of cluster members from cluster centroids was 3.711 of cluster number 2.

Table 5.1 Accessions taken in different clusters of the pooled data of years 2004-05 and 2005-06

Cluster number	**Accessions (for accession number refer to Appendix C)**
1	18 29 39 41 47 57 77 78 91 92 93 127 134 151 161 169
2	2 3 4 5 11 14 17 26 33 35 46 53 84 85 99 124 126 130 142 165 166
3	7 9 15 16 20 23 25 36 38 45 59 74 79 80 88 138 141 144
4	105
5	8 12 32 34 37 50 51 52 65 71 82 83 86 90 95 123 132 147 148 155 156 157 158 164 168 170
6	21 22 27 28 30 31 49 81 96 98 100 101 102 104 109 110 112 113 114 115 116 120 125 133 135 136 137 149 150 162 171
7	24 40 42 43 60 89 159 160
8	97 107 118 119 122 131 139 143 145 146
9	6 10 13 44 54 55 61 62 63 64 66 67 68 69 70 72 94 108 172
10	103 121
11	56 58 73 75 76 87 106 128 129 140 152 153 154
12	1 19 48 111 117 163 167

Table 5.2 Morphological character's mean and standard deviation for different clusters of pooled data of the years 2004-05 and 2005-06

Cluster No.	Days to 50 per cent flower	Days to total flower	Plant height	No. of nodes	No. of primary branch	No. of secondary branch	Stem girth	Leave Per plant	Leaf length	Leaf width	Leaf weight Per plant	Stem weight per plant	Dry stem weight plant	Dry weight per plant	Days to total maturity	No. of pod cluster per plant	No. of pods per plant	Pod length	No. of seeds per pod	No. of seeds per plant
1	49.62 ±6.53	66.78± 6.30	163.78 ± 20.06	20.29 ± 3.11	5.24 ± 0.87	3.82 ± 1.29	1.14±0 .14	67.15 ±11.72	12.86± 0.99	8.67 ±1.30	325.11 ±59.27	149.51 ±28.88	15.65 ±3.57	79.42 ±10.01	136.07 ± 4.32	5.74 ±2.47	14.99± 6.10	12.47± 1.82	11.57 ± 2.15	175.46 ± 74.97
2	59.98 ±9.96	76.10 ±10.48	158.92 ±30.51	22.28 ±2.76	6.62 ±1.28	7.87 ±3.02	1.32 ±0.16	93.89 ±23.25	11.54± 1.82	7.48 ±1.06	446.90 ±104.28	221.25 ±57.85	16.15 ±4.18	86.90 ±9.83	131.14 ±7.91	4.76 ±2.52	12.35 ±7.19	12.99± 2.19	11.71 ±2.69	139.72 ±77.79
3	46.78± 4.71	63.22 ±7.56	151.45 ± 25.34	19.28 ± 1.81	5.96 ± 1.17	4.00 ± 1.57	1.24 ±0.14	69.20± 19.41	11.81± 1.69	7.32 ±1.23	365.64 ±71.19	175.11 ±43.10	15.19 ±1.79	76.22 ±8.55	133.28 ± 5.60	6.85 ±3.03	19.35± 8.10	15.45± 1.96	16.11 ± 1.48	307.83 ± 120.83
4	47.00 ± 0.00	84.00± 0.00	205.72 ± 0.00	27.98 ± 0.00	8.58 ± 0.00	2.32 ± 0.00	1.36 ± 0.00	185.29 ± 0.00	14.25± 0.00	8.00 ± 0.00	503.33 ± 0.00	277.28 ± 0.00	16.72 ± 0.00	116.00 ± 0.00	135.00 ± 0.00	12.22 ± 0.00	28.31 ± 0.00	18.98± 0.00	20.82 ± 0.00	590.98 ± 0.00
5	52.10± 7.42	69.76 ±8.33	150.42 ±21.32	19.45 ± 2.78	4.98 ± 0.99	3.63 ±1.69	1.05 ±0.14	61.29 ±14.80	9.36± 0.77	5.82± 0.70	286.83 ±44.46	130.10 ±19.21	12.12 ±3.54	81.35 ±12.15	136.62 ±6.40	5.26 ±1.75	14.06 ±6.10	12.76± 1.85	12.32 ±2.31	173.23 ±81.91
6	68.84 ±10.47	93.29 ±6.08	149.70 ±24.33	21.25 ±2.48	5.60 ±0.80	4.88 ±1.92	1.26±0 .16	91.46 ±29.88	9.61± 2.19	5.97 ±1.38	386.53 ±85.17	211.45 ±52.65	14.65 ±2.22	109.58 ± 11.94	138.87 ±6.22	5.25 ± 2.62	11.85 ± 5.72	14.03± 1.70	13.52 ±2.20	159.97 ±82.28
7	56.19± 10.73	71.75 ±11.55	188.60 ±25.06	17.72 ±2.82	4.23 ±0.89	2.93 ±1.75	0.89 ±0.10	39.87 ±11.71	9.77 ±1.93	6.19 ±1.08	206.35 ±79.23	104.44 ±23.40	17.51 ±1.64	82.62 ±14.83	135.75 ±7.69	6.11 ±2.10	12.81 ±5.52	18.70± 4.18	17.60 ± 3.10	226.95 ± 100.67
8	48.60 ±9.98	82.65 ±13.95	148.20 ± 13.66	20.49± 2.07	5.49± 0.99	2.62 ±0.71	1.29±0 .17	70.62 ±22.53	11.95± 1.19	7.92± 0.83	382.48 ±52.92	176.99 ± 39.50	16.02± 1.97	100.40 ± 14.92	138.30 ± 5.10	15.39± 3.99	35.89 ±4.83	16.33± 1.99	14.63± 2.16	524.57 ± 107.08
9	49.35± 4.53	66.05 ±7.29	172.23 ±27.65	19.52 ±3.34	4.07± 0.73	2.60 ± 0.83	1.05 ±0.13	50.93 ±18.27	11.03± 1.55	7.25 ±0.89	237.17 ±72.00	115.36 ±27.67	11.84 ±2.46	78.05 ±7.73	120.91 ±6.01	8.45 ±3.38	23.07± 9.12	12.31± 2.25	11.51 ±1.92	269.60 ± 122.77
10	70.50 ±9.19	90.00± 9.19	179.82 ±21.59	22.83 ±0.74	6.16 ±0.37	11.67 ±1.53	1.69 ±0.28	173.98 ±38.29	9.57± 1.53	5.94 ±1.83	859.33 ±119.08	580.07 ±64.26	13.62 ±0.28	104.00 ±19.80	138.50 ±7.78	5.86 ±5.52	9.19 ±4.36	15.08± 3.32	14.16 ±4.99	141.52 ± 107.08
11	52.38 ±6.18	66.62± 4.33	154.04 ±24.38	21.30 ±3.17	5.39 ±1.30	2.91 ± 1.06	1.14 ±0.11	71.42 ±18.04	10.58± 1.00	6.72 ±0.82	331.33 ±54.19	150.23 ±25.44	15.46 ±3.19	78.62± 6.25	135.85 ±6.95	21.32 ±5.59	44.70 ±5.38	14.87± 2.92	14.06 ±2.82	616.21 ± 84.97
12	51.07 ±7.11	73.36 ±11.39	195.50 ±13.77	25.00± 2.67	5.20± 1.04	4.02 ± 1.33	1.34 ±0.23	78.56 ±8.97	11.90± 1.71	7.26 ±0.86	519.43 ±97.66	246.61 ±53.58	14.77± 3.26	80.71 ±12.34	134.00 ±7.66	12.84 ±3.66	31.44 ±5.50	16.79± 2.76	15.24 ±1.93	484.92 ± 82.65

Table 5.3 Distance between centroids of twelve clusters of the pooled data of years 2004-05 and 2005-06

Cluster	1	2	3	4	5	6	7	8	9	10	11	12
1	0.000											
2	3.390	0.000										
3	2.638	3.602	0.000									
4	8.384	7.501	7.423	0.000								
5	3.097	4.225	3.203	9.342	0.000							
6	4.577	3.310	4.462	7.742	3.829	0.000						
7	4.723	6.105	4.104	9.324	3.933	5.386	0.000					
8	4.296	5.004	3.434	6.605	4.921	4.716	5.411	0.000				
9	3.216	5.132	3.753	9.565	2.949	5.525	4.496	4.968	0.000			
10	10.311	7.642	9.741	9.042	10.460	7.991	11.781	10.009	11.589	0.000		
11	5.074	5.955	4.128	7.740	5.029	6.002	5.681	2.826	4.746	11.054	0.000	
12	4.650	4.500	3.690	5.865	5.383	5.144	5.827	3.332	5.269	8.514	3.854	0.000

Table 5.4 Average distances of cluster members from cluster centroids

Year	Cluster number												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
2005-06	2.772	2.911	2.039	3.359	3.040	3.012	2.975	3.920	2.805	3.495	3.325	3.365	2.882
2004-05	2.490	3.099	2.410	3.002	2.931	3.011	2.821	3.008	2.789	3.327	3.342	2.377	-
Pooled 2004-06	2.727	3.711	2.805	0.000	2.829	3.289	3.262	2.759	2.844	2.993	2.983	3.038	-

Clusters characteristics of some morphological attributes

The characterization of germplasm in to various clusters resulted in useful information. The major morphological attributes showing high effect for improving grain and grain yield, in the order of their importance, are given in Table 5.5.

Table 5.5 Major morphological attributes having high effect for improving grain and grain yield

Morphological attribute	Cluster number (in sequence from high to low)
Number of secondary branches	10, 2, 6, 12, 3, 1, 5, 7, 11, 8, 9, 4
Stem girth	10, 4, 12, 2, 8, 6, 3, 1, 11, 5, 9, 7
Number of pods per plant	11, 8, 12, 4, 9, 3, 1, 5, 7, 2, 6, 10
Number of seeds per plant	11, 4, 8, 12, 3, 9, 7, 1, 5, 6, 10, 2
Stem weight per plant	10, 4, 12, 2, 6, 8, 3, 11, 1, 5, 9, 7
Number of leaves per plant	4, 10, 2, 6, 12, 11, 8, 3, 1, 5, 9, 7

Cluster number 10 can be identified as having competent traits that can be utilized for improving fodder yield and cluster number 11 has lines with potential for seed yield. Thus cluster analysis helped in drawing representative sample from various segments of genetic stock for further utilization in never ending process of genetic manipulation. Shwe *et al.* (1972) and Kumari *et al.* (2000) observed better recombinants by crossing parents from clusters of high and low means for the characters under consideration. Therefore, it can be suggested that to have a better heterotic effect the genotypes from diverse clusters could be used for hybridization which may result in the desired recombinants.

5.2 Correlation

The correlation was established among different traits of the evaluated germplasm for the pooled data of the years 2004 and 2005. Correlation coefficients among different traits are shown in Table 5.6. The analysis revealed that, **early plant vigour** had a positive significant correlation (0.1654*) with plant growth habit and negative significant correlation with number of nodes (-0.1872*), number of leaves per plant (-0.1967*), leaf weight per plant (-0.2128**), stem weight per plant (-0.1513*), dry leaf weight per plant (-0.1813*), biomass per plant (-0.1865*), days to maturity initiation (-0.1538*) and days to total maturity (-0.2136*).

Plant growth habit had a significant and positive correlation with pod length (0.1623*) and 100 seed weight (0.1533*).

Days to 50 per cent flowering had a high significant correlation with days to total flowering (0.6530**), number of secondary branches (0.2676**), number of leaves per plant (0.3605**), stem weight per plant (0.2617**), dry stem weight per plant (0.3800**), dry weight per plant (0.2998*), days to maturity initiation (0.4560**) and days to total maturity (0.2154**). Days to 50 per cent flowering had a negative and highly significant correlation with leaf length (-0.2790**), leaf width (-0.3692**), leaf per stem ratio (-0.4085**), dry leaf stem ratio (-0.4119**), number of pods (-0.3138**) and number of seeds per plant (-0.3086**).

Days to total flowering had a significant and positive correlation with length of main branch (0.1824*), number of nodes (0.1815*), number of secondary branches (0.1877**), stem girth (0.2166**), number of leaves per plant (0.3201**), stem weight per plant (0.2957**), dry stem weight per plant (0.3728**) and biomass per plant (0.2347**). Days to total flowering had a negative, highly significant correlation with leaf length (-0.2379**), leaf width (-0.2066**), dry leaf stem ratio (-0.2797**), number of pods (-0.2040**), leaf per stem ratio (-0.1821*), dry weight per plant (0.3191**), days to maturity initiation (0.7585**) and days to total maturity (0.3428**).

Plant height had significant and a positive correlation with number of nodes (0.2092**), days to total maturity (-0.1828*), pod length (0.1828*) and seeds per pod (0.1529*).

Length of main branch had a high significant positive correlation with number of secondary branches (0.2267**), leaf weight per plant (0.2283**), stem weight per plant (0.3344**), dry stem weight per plant (0.3143**), biomass per plant (0.3118**), dry leaf weight per plant (0.1631*), dry weight per plant (0.2870**), days to total maturity (0.1636*). The same had negative correlation with dry leaf per stem ratio (-0.1776*).

Number of nodes had a highly significant positive correlation with number of primary branches (0.2150**), stem girth (0.3494**), leaves per plant (0.3786**), leaf weight per plant (0.3786**), leaf weight per plant (0.3404**), stem weight per plant (0.4102**), dry leaf weight per plant (0.3071**), dry weight per plant (0.3527**), dry stem weight per plant (0.3387**) and biomass per plant (0.4075**) and significant positive correlation with days to maturity initiation (0.1596*).

Number of primary branches had highly significant positive correlation with stem girth (0.4099**), number of leaves per plant (0.4663**), leaf length (0.1544**), leaf

weight per plant (0.3663**), stem weight per plant (0.3398**), dry leaf weight per plant (0.2863**), dry stem weight per plant (0.2832**), biomass per plant (0.3725**), dry weight per plant (0.3047**) and significant positive correlation with number of secondary branches (0.3808*) and 100 seed weight (0.1630*).

Number of secondary branches had highly significant positive correlation with stem girth (0.2893**), leaves per plant (0.5783**), leaf weight per plant (0.3889**), stem weight per plant (0.5515**), dry leaf weight per plant (0.3469**), dry stem weight per plant (0.5561**), biomass per plant (0.5194**), dry weight per plant (0.5270**) and significant positive correlation with days to maturity initiation (0.1851*). The same had highly significant negative correlation with dry leaf per stem ratio (-0.2862**), number of clusters (-0.2862**), number of pods (-0.2761**) and seeds per plant (-0.2997**) and significant negative correlation with number of seeds per pod (-0.1681*).

Stem girth had a highly significant positive correlation with number of leaves per plant (0.5024**), leaf length (0.2477**), leaf width (0.2026**), leaf weight per plant (0.4845**), stem weight per plant (0.5739**), dry leaf weight per plant (0.4801**), dry stem weight per plant (0.5046**), biomass per plant (0.5735**), dry weight per plant (0.5329**), 100 seed weight (0.1949**), and significant positive correlation with days to maturity initiation (0.1743*) and days to total maturity (0.1906*).

Number of leaves per plant showed highly significant positive correlation with leaf weight per plant (0.5661**), stem weight per plant (0.6325**), dry leaf weight per plant (0.5423**), dry stem weight per plant (0.6898**), biomass per plant (0.6454**), dry weight per plant (0.6907**), days to maturity initiation (0.3199**), days to total maturity (0.2141**) and significant negative correlation with dry leaf per stem ratio (-0.1613*).

Leaf length had highly significant positive correlation with leaf width (0.7352**), leaf weight per plant (0.2458**), dry leaf weight (0.2320**), leaf per stem ratio (0.3406**), and 100 seed weight (0.2270**) and significant positive correlation with dry leaf per stem ratio (0.3211*). The same had highly significant negative correlation with days to maturity initiation (-0.2499**).

Leaf width had highly significant positive correlation with leaf weight per plant (0.2481**), leaf per stem ratio (0.3869**), dry leaf per stem ratio (0.3461**) and significant positive correlation with dry leaf weight per plant (0.1864*). The same had highly significant negative correlation with days to maturity initiation (-0.2043**).

Leaf weight per plant had highly significant positive correlation with stem weight per plant (0.7551**), dry leaf weight per plant (0.8258**), dry stem weight per

plant (0.6206**), biomass per plant (0.9047**), leaf / stem ratio (0.4394**), dry weight per plant (0.7332**) and dry leaf per stem ratio (0.1656*).

Stem weight per plant had highly significant positive correlation with dry leaf weight per plant (0.7230**), dry stem weight per plant (0.8856**), biomass per plant (0.9624**), days to maturity initiation (0.2491**), dry weight per plant (0.8956**) and significant positive correlation with days to total maturity (0.1512*). The same had highly significant negative correlation with leaf stem ratio (-0.2036**) and dry leaf per stem ratio (-0.2626**).

Dry leaf weight per plant had highly significant positive correlation with dry stem weight per plant (0.6955**), biomass per plant (0.8117**), leaf/stem ratio (0.2477**), dry weight per plant (0.8463**) and dry leaf per stem ratio (0.2844**).

Dry stem weight per plant had highly significant positive correlation with dry weight per plant (0.9714**), biomass per plant (0.8324**), days to maturity initiation (0.3681**) and significant positive correlation with days to total maturity (0.1671*). The same had highly significant negative correlation with leaf per stem ratio (-0.2364**) and dry leaf per stem ratio (-0.3967**).

Biomass per plant had highly significant positive correlation with dry weight per plant (0.8856**) and days to maturity initiation (0.2035**).

Leaf/stem ratio had highly significant positive correlation with dry leaf/stem ratio (0.6176**), number of pods (0.3053**), seeds per plant (0.2528**) and significant positive correlation with number of clusters (0.1674*).

Dry weight per plant had highly significant positive correlation with days to maturity initiation (0.3159**) and significant positive correlation with days to total maturity (0.1588*). The same had significant negative correlation with dry leaf stem ratio (-0.2000*).

Dry leaf stem ratio had significant positive correlation with number of clusters (0.1874*) and number of pods (0.2034*). The same had highly significant negative correlation with days to maturity initiation (-0.2542**) and significant negative correlation with seeds per pod (-0.1649*).

100 seed weight had a high positive correlation with pod length (0.3526**), seeds per pod (01939*) and days to total maturity (0.1711*).

Days to maturity initiation had highly significant positive correlation with days to total maturity (0.2927**).

Days to total maturity had highly significant positive correlation with number of seeds per pod (0.2264**).

Number of clusters per plant had highly significant positive correlation with number of pods (0.8520**), number of seeds per plant (0.8220**).

Number of seeds per pod had significant positive correlation with pod length (0.1884*) and number of seeds per pod (0.1564*).

Number of pods per plant had highly significant positive correlation with seeds per plant (0.9314**).

Pod length had highly significant positive correlation with number of seeds per pod (0.8029**) and number of seeds per plant (0.3801**).

Number of seeds per pod had highly significant positive correlation with number of seeds per plant (0.3821**).

Table 5.6 Correlation coefficients among recorded traits of the pooled data for the years 2004 and 2005

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.0000	0.1654*	-0.0510	-0.1031	0.0472	-0.0697	-0.1872*	-0.1321	-0.0800	-0.1054	-0.1967*	-0.1067	0.0264	-0.2128**	-0.1513*	-0.1813*	-0.1203	-0.1865*
2		1.0000	0.0348	0.0563	0.0216	0.0661	-0.1306	-0.0158	0.0993	0.1489	-0.0225	-0.0337	-0.1030	-0.0148	0.0979	0.0050	0.0684	0.0575
3			1.0000	0.6530**	-0.0302	0.0879	0.1368	0.1420	0.2676**	0.1364	0.3605**	-0.2790**	-0.3692**	-0.0739	0.2617**	0.0548	0.3800**	0.1394
4				1.0000	-0.0683	0.1824*	0.1815*	0.1027	0.1877**	0.2166**	0.3201**	-0.2379**	-0.2066**	0.1027	0.2957**	0.1292	0.3728**	0.2347**
5					1.0000	0.0882	0.2092**	-0.1298	-0.1233	-0.0262	-0.0355	0.1292	0.1023	0.0404	0.0929	0.0044	0.0691	0.0771
6						1	0.1417	0.1144	0.2267**	0.1504	0.1347	-0.0829	-0.0001	0.2283**	0.3344**	0.1631*	0.3143**	0.3118**
7							1.0000	0.2150**	0.1159	0.3494**	0.3786**	0.1284	0.0818	0.3404**	0.4102**	0.3071**	0.3387**	0.4075**
8								1.0000	0.3808*	0.4099**	0.4663**	0.1544*	0.0591	0.3663**	0.3398**	0.2863**	0.2832**	0.3725**
9									1.0000	0.2893**	0.5783**	-0.1233	-0.0782	0.3889**	0.5515**	0.3469**	0.5561**	0.5194**
10										1.0000	0.5024**	0.2477**	0.2026**	0.4845**	0.5739**	0.4801**	0.5046**	0.5735**
11											1.0000	0.0124	-0.0106	0.5661**	0.6325**	0.5423**	0.6898**	0.6454**
12												1	0.7352**	0.2458**	0.0087	0.2320**	-0.0613	0.1075
13													1.0000	0.2481**	-0.0195	0.1864*	-0.0968	0.0901
14														1.0000	0.7551**	0.8258**	0.6206**	0.9047**
15															1.0000	0.7230**	0.8856**	0.9624**
16																1.0000	0.6955**	0.8117**
17																	1.0000	0.6324**
18																		1

Table 5.5 Cont...

Traits: 1: Early Plant Vigour, 2: Plant Growth Habit, 3 : Days to 50 per cent Flowering, 4: Days to Total Flowering, 5: Plant Height, 6: Length of Main Branch, 7: Number of Nodes, 8: Number of Primary Branches, 9: Number Of Secondary Branches, 10: Stem Girth, 11: Number of Leaves per Plant, 12: Leaf Length, 13: Leaf Width, 14: Leaf Weight per Plant, 15: Stem Weight per Plant, 16: Dry Leaf Weight per Plant, 17: Dry Stem Weight per Plant , 18: Biomass per Plant, 19: Fresh Leaf Stem Ratio, 20: Dry Weight per Plant, 21: Dry Leaf per Stem Ratio, 22: 100 Seed Weight, 23: Days to Maturity Initiation, 24: Days to Total Maturity, 25: Number of Pod Clusters per Plant, 26: Number of Pods per Plant, 27: Pod Length, 28: Number of Seeds per Pod, 29: Number of Seeds per Plant.

Table 5.6 Cont…

	19	20	21	22	23	24	25	26	27	28	29
1	-0.1300	-0.1492	-0.0544	-0.0224	-0.1538*	-0.2136**	-0.0561	-0.0293	-0.0471	-0.1162	-0.0668
2	-0.1288	0.0523	-0.0893	0.1533*	-0.0265	0.0192	-0.0654	-0.0636	0.1623*	0.0911	-0.0205
3	-0.4085**	0.2998**	-0.4119**	0.1392	0.4560**	0.2154**	-0.1943*	-0.3138**	-0.0580	-0.0272	-0.3086**
4	-0.1821*	0.3191**	-0.2797**	0.0721	0.7585**	0.3428**	-0.1209	-0.2040**	0.0662	0.0596	-0.1602
5	-0.0863	0.0526	-0.0522	0.0836	-0.0832	-0.1828**	0.0247	0.0255	0.1828*	0.1529*	0.0753
6	-0.1054	0.2870**	-0.1776*	-0.0426	0.0878	0.1636**	-0.0546	-0.0706	0.1343	0.1043	0.0034
7	-0.0245	0.3527**	-0.0379	0.0569	0.1596*	0.0330	0.0362	0.0119	0.0461	0.0767	0.0653
8	0.1216	0.3047**	-0.0606	0.1630*	0.1234	0.1346	0.0256	-0.0341	0.0055	0.0983	-0.0071
9	-0.1479	0.5270**	-0.2862**	-0.0520	0.1851**	0.0572	-0.2862**	-0.2761**	-0.1240	-0.1681*	-0.2997**
10	-0.0274	0.5329**	-0.1116	0.1949**	0.1743**	0.1906**	0.0341	0.0109	0.0702	0.0398	0.0276
11	0.0459	0.6907**	-0.1613*	0.0087	0.3199**	0.2141**	-0.0662	-0.0926	-0.0762	-0.0615	-0.0992
12	0.3406**	0.0313	0.3211**	0.2270**	-0.2499**	-0.1337	0.1064	0.1268	0.0981	0.0370	0.1407
13	0.3869**	-0.0101	0.3461**	0.1039	-0.2043**	-0.1019	0.0678	0.1346	0.0110	-0.0163	0.1305
14	0.4394**	0.7332**	0.1656*	0.1205	0.1006	0.1252	0.0673	0.1232	0.0372	-0.0175	0.1234
15	-0.2036**	0.8956**	-0.2626**	0.1197	0.2491**	0.1512*	-0.0472	-0.0813	0.0776	0.0552	-0.0418
16	0.2477**	0.8463**	0.2844**	0.0826	0.1300	0.1057	0.0238	0.0114	0.0265	-0.0377	0.0153
17	-0.2364	0.9714**	-0.3967**	0.0959	0.3681**	0.1671*	-0.0964	-0.1266	0.1111	0.1008	-0.0773
18	0.0496	0.8856**	-0.1021	0.1277	0.2035**	0.1501*	-0.0028	-0.0018	0.0658	0.0286	0.0240
19	1.0000	-0.0933	0.6176**	0.0138	-0.1051	0.0204	0.1674*	0.3053**	-0.0401	-0.0852	0.2528**
20		1.0000	-0.2000**	0.0984	0.3159**	0.1588*	-0.0636	-0.0901	0.0911	0.0623	-0.0523
21			1.0000	-0.1278	-0.2542**	-0.1112	0.1874*	0.2034**	-0.1391	-0.1649*	0.1475*
22				1.0000	0.0452	0.1711*	0.0391	-0.0194	0.3526**	0.1939*	0.0410
23					1.0000	0.2927**	-0.0822	-0.1278	0.0567	0.0392	-0.1059
24						1	-0.0092	-0.0642	0.1438	0.2264**	0.0128
25							1.0000	0.8520**	0.1884*	0.1564*	0.8220**
26								1.0000	0.1340	0.0729	0.9314**
27									1.0000	0.8029**	0.3801**
28										1.0000	0.3821**
29											1

Traits: 1: Early Plant Vigour, 2: Plant Growth Habit, 3 : Days to 50 per cent Flowering, 4: Days to Total Flowering, 5: Plant Height, 6: Length of Main Branch, 7: Number Of Nodes, 8: Number Of Primary Branches, 9: Number Of Secondary Branches, 10: Stem Girth, 11: Number Of Leaves per Plant, 12: Leaf Length, 13: Leaf Width, 14: Leaf Weight per Plant, 15: Stem Weight per Plant, 16: Dry Leaf Weight per Plant, 17: Dry Stem Weight per Plant , 18: Biomass per Plant, 19: Fresh Leaf Stem Ratio, 20: Dry Weight per Plant, 21: Dry Leaf per Stem Ratio, 22: 100 Seed Weight, 23: Days to Maturity Initiation, 24: Days to Total Maturity, 25: Number Of Pod Clusters per Plant, 26: Number Of Pods per Plant, 27: Pod Length, 28: Number Of Seeds per Pod, 29: Number Of Seeds per Plant.

5.3 Path coefficient analysis

Using pooled data of the years 2004-05 and 2005-06, three sets of path coefficient analysis were performed. It was used to ascertain the direct and indirect contribution of different characters towards biomass per plant, dry weight per plant and number of seeds per plant.

With biomass per plant as dependant variable and (days to 50 per cent flowering, days to total flower, plant height, number of nodes, number of primary branches, number of secondary branches, stem girth, leaves per plant, leaf length and leaf width) as independent variables, it was found that low direct effect was shown by days to total flowering (0.1271), number of nodes (0.1335) and plant height (0.1028), moderate direct effect on biomass per plant was showed by number of secondary branches (0.2788) and stem girth (0.2842), and a high direct effect by leaves per plant (0.3251); Whereas negative, low direct effect by days to 50 per cent flowering (-0.1905). Table 5.7 shows path coefficients with biomass per plant as dependent variable.

Number of leaves per plant showed low indirect effect through days to total flower (0.1041), days to 50 per cent flowering (0.1172), number of nodes (0.1231), number of primary branches (0.1516), secondary branches (0.1880) and stem girth (0.1633). Number of secondary branches also showed indirect and low effect through number of leaves per plant (0.1612) and number of primary branches (0.1061). Also stem girth showed indirect and low effect through number of leaves per plant (0.1428) and number of primary branches (0.1165). Days to 50 per cent flowering also showed negative indirect and low effect through days to total flower (-0.1244).

With dry weight per plant as dependent variable and (days to 50 per cent flowering, days to total flowering, plant height, length of main branch, number of nodes, number of primary branches, number of secondary branches, stem girth, leaves per plant, leaf length and leaf width, leaf per stem ratio and dry leaf per stem ratio) as independent variables; low direct effect was shown by length of main branch (0.1387), negative low direct effect was shown by number of primary branches (-0.1058). Moderate and direct affect on dry weight per plant was shown by number of secondary branches (0.2005), stem girth (0.2336) and very high direct effect by leaves per plant (0.4598). Indirect low affect was shown by leaves per plant through days to 50 per cent flowering (0.1658), number of nodes (0.1741) and moderate indirect effect through number of primary (0.2144), secondary branches (0.2659) and stem girth (0.2310). Indirect low effect was also shown by number of secondary branches (0.1160) and stem girth (0.1174) through

number of leaves per plant. Table 5.8 shows path coefficient with dry weight per plant as dependent variable.

With number of seeds per plant as dependent variable and [days to 50 per cent flowering, days to total flowering, plant height, number of nodes, number of primary branches, number of secondary branches, stem girth, leaves per plant, leaf length, leaf width, biomass per plant, leaf per stem ratio, 100seed weight, days to maturity initiation, days to total maturity, number of clusters, number of pods, pod length, seeds per pod] as independent variables; it was found that very high direct affect was shown by seeds per pod (0.3059) and number of pods (0.9059) on seeds per plant. Indirect moderate effect on seeds per plant was shown by seeds per pod through pod length (0.2456). Indirect moderate effect was also shown by number of pods through [leaf per stem ratio (0.2765) and number of clusters (0.7718)]. Indirect low effect was shown by number of pods through [leaf length (0.1148), leaf width (0.1219) and pod length (0.1213)].

Negative moderate effect on seeds per plant was shown through [days to 50 per cent flowering (-0.2843) and number of secondary branches (-0.2501)]. Negative low effect on seeds per plant was shown through [days to maturity initiation (-0.1158) and days to total flower (-0.1848)]. Table 5.9 shows path coefficients with number of seeds per plant as dependent variable.

Similar results were shown by Kumar *et. al.* (2003) where correlation studies revealed significant and positive association of seed yield per plant with clusters per plant, pods per plant and 100 seed weight. In this study, days to maturity had the maximum and desirable direct as well as indirect effects on seed yield per plant. This study therefore suggested that selection based on three characters *viz.* 100 seed weight, cluster per plant and pods per plant; might bring simultaneous improvement in seed yield.

Estimates of the phenotypic and genotypic correlation coefficients, exhibited similar trends as reported by Parmar *et. al.* (2003) where, grain yield showed significant positive association with number of clusters per plant and pods per plant at phenotypic and genotypic levels. Other significant positive genotypic correlations were among [days to flower with days to maturity (0.467); and plant height (0.436)]; [days to maturity with plant height (0.563)]; [pod length with seeds per pod (0.429)]; [plant height with test weight (0.368)]; [branches per plant with clusters per plant (0.511)]; [clusters per plant with pods per plant (0.949)]; and [pods per cluster with pods per plant (0.649)]. Pods per plant registered the highest direct effect on seed yield, followed by clusters per plant and seeds per pod. The indirect effects of branches per plant through seeds per pod were also positive and high. Based on the findings it was suggested Parmar *et. al.* (2003) to lay

more emphasis on pods per plant, clusters per plant, seeds per pod, test weight and pods per cluster in selection programmes aiming to improve grain yields in cowpea.

The highest significant correlation or association was found between [dry weight per plant and dry stem weight per plant (0.9714**)]; followed by between [number of seeds per plant and number of pods per plant (0.9314**)]; and between [biomass per plant and stem weight per plant (0.9624**)] as shown in Fig 5.1.

The high correlation value mainly came from positive direct effect (0.4598) of dry weight per plant; stem girth ((0.2336); and number of secondary branches (0.2005).

The high correlation value of biomass per plant mainly came from positive direct effect of number of leaves per plant (0.3251); stem girth (0.2842); and number of secondary branches (0.2788).

The high correlation value of number of seeds per plant mainly came from direct positive effect of number of pods per plant (0.9059); and through indirect effect of number of pod cluster per plant (0.7718).

In a similar study Niazi *et. al.* (1999) have conducted path-coefficient analysis for *Vigna radiata* and concluded that a plant type for increased fodder and grain yield should have higher biomass per plant, dry weight per plant and seed yield per plant. In this study, pods per plant emerged as a reliable trait that can serve as a selection criterion in breeding high yielding cultivars of *Vigna radiata*. Therefore, in the present study, a high impact of direct effects of correlation suggested that going for plant types with higher biomass per plant, dry weight per plant, stem girth, number of secondary branches, number of leaves per plant, number of pods per plant, and number of pod cluster per plant would be effective for improving fodder and seed yield in cowpea.

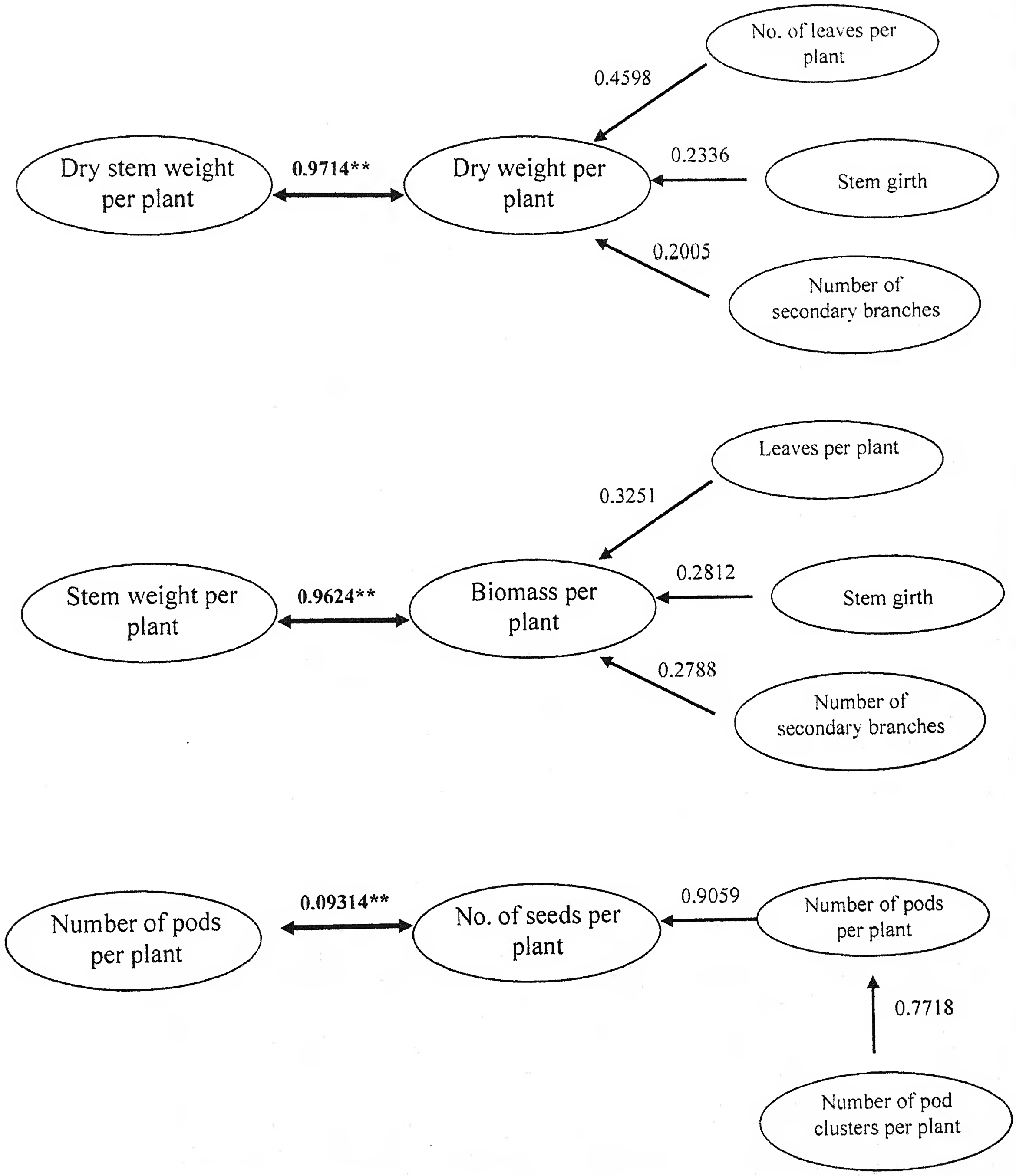


Fig. 5.1 Highest significant correlation coefficients (double headed arrow lines) and path coefficients (single headed arrow lines) for the path analysis of pooled data for the years 2004-05 and 2005-06.

Table 5.7 Path coefficients with biomass per plant as dependent variable

	1	2	3	4	5	6	7	8	9	10
1	**-0.1905**	0.0830	-0.0031	0.0183	-0.0011	0.0746	0.0388	0.1172	-0.0125	0.0149
2	-0.1244	**0.1271**	-0.0070	0.0242	-0.0008	0.0523	0.0616	0.1041	-0.0107	0.0083
3	0.0058	-0.0087	**0.1028**	0.0279	0.0010	-0.0344	-0.0074	-0.0116	0.0058	-0.0041
4	-0.0261	0.0231	0.0215	**0.1335**	-0.0017	0.0323	0.0993	0.1231	0.0058	-0.0033
5	-0.0270	0.0131	-0.0133	0.0287	**-0.0077**	0.1061	0.1165	0.1516	0.0069	-0.0024
6	-0.0510	0.0238	-0.0127	0.0155	-0.0029	**0.2788**	0.0822	0.1880	-0.0055	0.0032
7	-0.0260	0.0275	-0.0027	0.0466	-0.0032	0.0806	**0.2842**	0.1633	0.0111	-0.0082
8	-0.0687	0.0407	-0.0037	0.0505	-0.0036	0.1612	0.1428	**0.3251**	0.0006	0.0004
9	0.0531	-0.0302	0.0133	0.0171	-0.0012	-0.0344	0.0704	0.0040	**0.0449**	-0.0296
10	0.0703	-0.0263	0.0105	0.0109	-0.0005	-0.0218	0.0576	-0.0035	0.0330	**-0.0403**

Independent variables: 1: Days to 50 per cent flowering; 2: Days to total flowering; 3: Plant height; 4: number of nodes; 5: number of primary branches; 6: number of secondary branches; 7: Stem girth; 8: Number of leaves per plant; 9: Leaf length; and 10 : leaf width.

Table 5.8 Path coefficients with dry weight per plant as dependent variable

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**-0.0254**	0.0545	-0.0019	0.0122	0.0064	-0.0150	0.0537	0.0319	0.1658	-0.0269	0.0343	0.0220	-0.0116
2	-0.0166	**0.0834**	-0.0043	0.0253	0.0085	-0.0109	0.0376	0.0506	0.1472	-0.0229	0.0192	0.0098	-0.0079
3	0.0008	-0.0057	**0.0628**	0.0122	0.0098	0.0137	-0.0247	-0.0061	-0.0163	0.0125	-0.0095	0.0046	-0.0015
4	-0.0022	0.0152	0.0055	**0.1387**	0.0067	-0.0121	0.0455	0.0351	0.0619	-0.0080	0.0000	0.0057	-0.0050
5	-0.0035	0.0151	0.0131	0.0197	**0.0470**	-0.0227	0.0232	0.0816	0.1741	0.0124	-0.0076	0.0013	-0.0011
6	-0.0036	0.0086	-0.0082	0.0159	0.0101	**-0.1058**	0.0764	0.0958	0.2144	0.0149	-0.0055	-0.0066	-0.0017
7	-0.0068	0.0157	-0.0077	0.0314	0.0054	-0.0403	**0.2005**	0.0676	0.2659	-0.0119	0.0073	0.0080	-0.0081
8	-0.0035	0.0181	-0.0016	0.0209	0.0164	-0.0434	0.0580	**0.2336**	0.2310	0.0239	-0.0188	0.0015	-0.0032
9	-0.0091	0.0267	-0.0022	0.0187	0.0178	-0.0493	0.1160	0.1174	**0.4598**	0.0012	0.0010	-0.0025	-0.0046
10	0.0071	-0.0198	0.0081	-0.0115	0.0060	-0.0163	-0.0247	0.0579	0.0057	**0.0964**	-0.0682	-0.0184	0.0091
11	0.0094	-0.0172	0.0064	0.0000	0.0038	-0.0063	-0.0157	0.0473	-0.0049	0.0709	**-0.0928**	-0.0209	0.0098
12	0.0104	-0.0152	-0.0054	-0.0146	-0.0011	-0.0129	-0.0296	-0.0064	0.0211	0.0328	-0.0359	**-0.0539**	0.0175
13	0.0104	-0.0233	-0.0033	-0.0246	-0.0018	0.0064	-0.0574	-0.0261	-0.0742	0.0309	-0.0321	-0.0333	**0.0283**

Independent variables: 1: Days to 50 per cent flowering; 2: Days to total flowering; 3: Plant height; 4:length of main branch; 5: number of nodes; 6: number of primary branches; 7: number of secondary branches; 8: Stem girth; 9: number of leaves per plant; 10: Leaf length; 11: leaf width; 12: fresh leaf per stem ratio; and 13: dry leaf per stem ratio.

Table 5.9 Path coefficients with number of seeds per plant as dependent variable

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	-0.0383	0.0258	0.0002	0.0046	-0.0018	0.0020	-0.0019	-0.0002	-0.0042	0.0007	0.0015	0.0041	-0.0002	-0.0087	0.0007	0.0003	-0.2843	-0.0005	-0.0083
2	-0.0250	0.0395	0.0005	0.0061	-0.0013	0.0014	-0.0030	-0.0002	-0.0036	0.0004	0.0026	0.0018	-0.0001	-0.0145	0.0010	0.0002	-0.1848	0.0006	0.0182
3	0.0012	-0.0027	-0.0071	0.0071	0.0017	-0.0009	0.0004	0.0000	0.0020	-0.0002	0.0008	0.0009	-0.0001	0.0016	-0.0006	0.0000	0.0231	0.0016	0.0468
4	-0.0052	0.0072	-0.0015	0.0338	-0.0028	0.0009	-0.0048	-0.0002	0.0019	-0.0002	0.0045	0.0002	-0.0001	-0.0031	0.0001	-0.0001	0.0108	0.0004	0.0235
5	-0.0054	0.0041	0.0009	0.0073	-0.0129	0.0029	-0.0056	-0.0003	0.0023	-0.0001	0.0041	-0.0012	-0.0003	-0.0024	0.0004	0.0000	-0.0309	0.0000	0.0301
6	-0.0102	0.0074	0.0009	0.0039	-0.0049	0.0075	-0.0040	-0.0004	-0.0019	0.0002	0.0057	0.0015	0.0001	-0.0035	0.0002	0.0004	-0.2501	-0.0011	-0.0514
7	-0.0052	0.0085	0.0002	0.0118	-0.0053	0.0022	-0.0137	-0.0003	0.0038	-0.0004	0.0063	0.0003	-0.0003	-0.0033	0.0006	0.0000	0.0099	0.0006	0.0122
8	-0.0138	0.0126	0.0003	0.0128	-0.0060	0.0044	-0.0069	-0.0006	0.0002	0.0000	0.0071	-0.0005	0.0000	-0.0061	0.0007	0.0001	-0.0838	-0.0007	-0.0188
9	0.0107	-0.0094	-0.0009	0.0043	-0.0020	-0.0009	-0.0034	0.0000	0.0151	-0.0015	0.0012	-0.0034	-0.0004	0.0048	-0.0004	-0.0002	0.1148	0.0009	0.0113
10	0.0141	-0.0082	-0.0007	0.0028	-0.0008	-0.0006	-0.0028	0.0000	0.0111	-0.0020	0.0010	-0.0039	-0.0002	0.0039	-0.0003	-0.0001	0.1219	0.0001	-0.0050
11	-0.0053	0.0093	-0.0006	0.0138	-0.0048	0.0039	-0.0079	-0.0004	0.0016	-0.0002	0.0110	-0.0005	-0.0002	-0.0039	0.0005	0.0000	-0.0016	0.0006	0.0088
12	0.0156	-0.0072	0.0006	-0.0008	-0.0016	-0.0011	0.0004	0.0000	0.0052	-0.0008	0.0005	-0.0100	0.0000	0.0020	0.0001	-0.0002	0.2765	-0.0004	-0.0261
13	-0.0053	0.0028	-0.0006	0.0019	-0.0021	-0.0004	-0.0027	0.0000	0.0034	-0.0002	0.0014	-0.0001	-0.0017	-0.0009	0.0005	-0.0001	-0.0175	0.0032	0.0593
14	-0.0174	0.0299	0.0006	0.0054	-0.0016	0.0014	-0.0024	-0.0002	-0.0038	0.0004	0.0022	0.0010	-0.0001	-0.0192	0.0009	0.0001	-0.1158	0.0005	0.0120
15	-0.0082	0.0135	0.0013	0.0011	-0.0017	0.0004	-0.0026	-0.0001	-0.0020	0.0002	0.0016	-0.0002	-0.0003	-0.0056	0.0030	0.0000	-0.0582	0.0013	0.0692
16	0.0074	-0.0048	-0.0002	0.0012	-0.0003	-0.0022	-0.0005	0.0000	0.0016	-0.0001	0.0000	-0.0017	-0.0001	0.0016	0.0000	-0.0014	0.7718	0.0017	0.0478
17	0.0120	-0.0081	-0.0002	0.0004	0.0004	-0.0021	-0.0001	0.0001	0.0019	-0.0003	0.0000	-0.0030	0.0000	0.0024	-0.0002	-0.0012	0.9059	0.0012	0.0223
18	0.0022	0.0026	-0.0013	0.0016	-0.0001	-0.0009	-0.0010	0.0000	0.0015	0.0000	0.0007	0.0004	-0.0006	-0.0011	0.0004	-0.0003	0.1213	0.0090	0.2456
19	0.0010	0.0024	-0.0011	0.0026	-0.0013	-0.0013	-0.0005	0.0000	0.0006	0.0000	0.0003	0.0008	-0.0003	-0.0008	0.0007	-0.0002	0.0660	0.0072	0.3059

Independent variables: 1: Days to 50 per cent flowering; 2: Days to total flowering; 3: Plant height; 4: number of nodes; 5: number of primary branches; 6: number of secondary branches; 7: Stem girth; 8: number of leaves per plant; 9: Leaf length; 10: leaf width; 11: Biomass per plant; 12: fresh leaf per stem ratio; 13: 100seed weight; 14: Days to maturity initiation; 15: days to total maturity; 16: number of pod clusters per plant; 17: number of pods per plant; 18: Pod length; and 19: number of seeds per plant.

5.4 Identification of donor sources

Morphological evaluation of *V. unguiculata* germplasm (including three cultigroups *viz. unguiculata, catjang* ,and *sesquipedalis*) procured from local and indigenous regions, led to the identification of promising donor sources. The traits revealed by the study were well defined. These traits were utilized for identification of germplasm lines with respect to any specific purpose. In the present study, the prime factors of concern were forage and grain production. So, the traits identified for these factors are discussed as following.

5.4.1 Identification of donor sources in respect of forage

Higher biomass per plant were obtained for the accessions [IL-1177 (943.5); IL-3171 (775.1); and IL-966-B (663.7)] and higher fresh leaf per stem ratios were for genotypes [HY6P52-3 (1.04); IL-893 (1.01); and IL-99-171 (0.95)]. In case of dry matter yield, accessions [IL-1177 (625.51); IL-3171 (543.63); and IL-449 (345.94)] were high yielding. Accessions that showed higher dry Leaf per Stem ratio were [IL-160-A (1.02); IL-99-98-1 (0.97); and (IL-792 (0.94. The cluster analysis of pooled data for the years 2004-05 and 2005-06 grouped higher fodder yielding lines IL-3171 and IL-1177 in cluster number 10 with maximum mean value of fresh biomass per plant being as 859.33±119.08 g and dry biomass per plant being as 580.07±64.26 g. Earlier flowering lines were identified as EC-240564 and EC-244979 showing 50 per cent flowering in 38 DAS. These lines enable quick (38 DAS) harvest of the crop for green fodder purpose.

5.4.2 Identification of donor sources in respect of grain and grain yield

Lines identified for early maturity initiation (76 DAS) were EC240887, HY6P 52-3, HY-10P58-3, EC120001, EC240714, NP-3-10, HY5P, HY-5P-6S-215, EC-240800, EC-244217-1, HY-5p-32-2b, IL-55-1, IL-15-1, IL-132, IL-160, IL-2000-184, IL-419-2, IL-1086-2 and IL-887.

The heaviest seed bearing lines identified with 100 seed weight were IL-181 (25.2 g); IL-4216 (22.6 g); and IL-156 (22.5 g). The highest numbers of seeds per plant bearing lines were IL-90, EC-240809, IL 3117, IL-155-1, IL-3168-A, IL-200-180, IL-160-9, IL-156, IL-1182, IL-14177-A, IL-1156-1, IL-1177-B and EC-24102-1 with a mean value of 616 seeds per plant.

The lines with higher number of pod clusters per plant were IL-178-4, IL-622, IL-362, IL-812-1, IL-867, IL-380B, IL-893-1, IL-216-1, IL-160-11, and IL-1721 with a mean value of 15 pod clusters per plant. The maximum pod bearing lines identified were IL-90, EC-240809, IL 3117, IL-155-1, IL-3168-A, IL-200-180, IL-160-9, IL-156, IL-1182, IL-14177-A, IL-1156-1, IL-1177-B, and EC-24102-1 with a mean value of 45 pods per plant. Longest pod bearing lines identified were Local 1 (24.6 cm); IL 2000-182 (24.4 cm); and NP 3-7 (21.8 cm).

Highest numbers of seeds per pod bearing lines were Local-2 (22); Local-1(21); and IL 1057 (21).

5.5 Use of studied morphological, cytological and biochemical traits in breeding

The lines identified as donor sources of early maturity, erect plant habit, less days to 50 per cent flowering, higher fodder yield, more leafy lines, higher leaf per stem ratio, higher number of pod bearing, longer pod bearing and more seed per plant bearing lines can be utilized in further breeding programmes. Some of these lines *viz.* IL1177 (higher fodder yielding line), EC 24102-1, IL-2000-184, EC240884, IL-156 have also been characterized at biochemical level by isozyme analysis and chemical seed tests for establishing their uniqueness and identities.

The identified donor sources *viz.* EC-24102-1 [for highest number of seeds per plant (about 600) and higher number of pods per plant (about 45)], IL-2000-184 [for early maturity initiation (76 DAS)], IL-1177 [for higher biomass per plant (943.5g) and higher dry weight per plant (625.5g)], EC 240564 [for early 50 per cent flowering in 38 DAS]; IL-156 [for heavy seed (22.5 g , 100 seed weight) and higher number of seeds per pod (about 600)] have been characterized at biochemical, isozyme level. Higher green and dry fodder yielding line IL-1177 has also been studied for chromosomal associations. Therefore the above lines can be easily utilized in breeding programme.

At isozyme level, no difference was observed amongst the identified donor sources in esterase profile due to monomorphic bands being present. However, isozymes, Poly phenol oxidase, peroxidase and SDS PAGE showed polymorphic bands and identified donors could be distinguished. The esterase profile of the identified donor sources showed that band 1 was absent and bands 2, 3, 4, 5, 6, 7, 8, 9 and 10 were present in all the 6 lines. These results are contrary to Reis and Frederico

(2001) where esterase zymograms were polymorphic. This may be due to taking into consideration only few identified donor sources lines.

The comparative analysis of PPO, SDS and peroxidase zymograms can characterize the lines (donor sources). Poly phenol oxidase profile of donor sources mentioned above was as follows: band 5, 6, 7 were absent in EC 240102-1, whereas bands 5, 6, 7 were present in IL-2000-184. Band 7 was present in IL-1177, EC-240884, EC-240564 and IL-156, band 6 was present in EC 240884 and band 5 was present in IL-1177.

Peroxidase isozyme profile showed that line EC 24102-1 had only bands 4 and 9, line IL-2000-184 showed all the bands except band 3. Line IL-1177 showed only bands 2 and 9, line EC 240884 showed only bands 1, 2 and 9, line EC 240564 showed only bands 1 and 2, line IL-156 showed bands 1, 2, 3 and 5.

SDS PAGE profile of six identified donor sources showed that line EC 240884 and IL-156 had all 9 bands. Line EC 24102-1 had all the bands except 6 and 7, line IL-2000-184 showed only bands 5, 6, 7, 8 and 9, line IL-1177 showed only bands 3 and 5, line EC 240564 showed all the bands except 1, 7 and 8.

As far as isozyme profile of different cultigroups are concerned, no cultigroup specific bands were identified (Table 4.11 of Chapter 4), as earlier reported by Vaillancourt *et. al.* (1993). However, different accessions of the cultigroups showed distinct isozyme profiles. Amongst the four isozyme profiles studied, esterase isozyme profile was the most polymorphic as earlier reported by Reis and Frederico (2001).

Chromosomal associations have been studied in representative genotypes of the three cultigroups including the identified higher fodder yielding line IL-1177. Cytological study showed that configurations of more than 4 chromosomes have not been observed, indicating that there is little, if any, role of gross structural changes in the evolution of different cultigroups. However, the occurrence of multivalent per univalent configurations in meiotic system is an indicator of hybridity involved in the origin of different cultigroups (Pandey and Roy, 2006).

5.6 Hypothesis and conclusion

Collection of the germplasm with favourable traits in respect of forage and grain yield of cowpea, hypothesized, was done on one platform for further utilization of developing varieties having traits of early maturity, determinate growth habit and

high forage and grain yield. With the introduction of plant variety Protection Act under GATT, the need for precise genotypic characterization with clear Distinctness (D), Uniformity (U) and Stability (S) have been addressed in this work. The biometrical analysis of evaluated germplasm made possible the following.

a) Assessment of genetic variability in the germplasm
b) Selection of elite accessions from the germplasm
c) Choice of parents for hybridization.

The cytological and biochemical characterization of representative genotypes were established from similar groups within the germplasm.

CHAPTER 6

EXECUTIVE SUMMARY

Cowpea, *Vigna unguiculata* (L) Walp., is a grain legume crop well adapted to many areas of the humid tropics and temperate zones. It tolerates heat and dry conditions, but frost. The crop performs best on well-drained sandy loams or sandy soils where pH is in the range of 5.5 to 6.5. Its origin and subsequent domestication is associated with pearl millet and sorghum in Africa. Cowpea has high protein content and fixes atmospheric nitrogen, which allows it to grow on and improve poor soils. Its young leaves, immature pods and peas are used as vegetables, while seeds are used for making snacks and main meal. Its multiple uses are as animal fodder, as green manure crop and as a crop for soil erosion control. Cowpea is considered nutritious with its seed containing about 23 per cent protein, 1.3 per cent fat, 1.8 per cent of fiber, 67 per cent carbohydrate and 8 to 9 per cent water.

With the use of suitable genotypes and proper inputs, the production of cowpea can be considerably enhanced. There exists a need for developing varieties with early maturity, determinate growth habit and high yield. Classical methods of characterization are based exclusively on agro morphological and physiological traits. So, more sensitive and robust characterization methods like biochemical and cytological characterization need to address the limitations associated with morphological markers. Therefore, this study has been taken with the following objectives.

Objectives

1. Evaluation of germplasm lines for forage and grain yield and yield attributes, character correlation and path analysis for determining the contribution of various traits to forage and grain yield.
2. Establishing distinctness of lines based on some morphological, physiological and biochemical traits for further utilization in breeding programme.

In order to take up this work, a wide range of genotypes from local and indigenous region were procured and evaluated to study the morphological performance. **A total of 172 lines of cowpea** including three checks and one control were evaluated in

the farm of Crop Improvement Division of Indian Grassland and Fodder Research Institute, Jhansi in the years 2004-05 and 2005-06. The evaluations were performed in augmented design. Three lines kept as checks were Bundel lobia-1, Bundel lobia-2, UPC-5286 and the control was local IGFRI-95-1. Observations were recorded according to the minimal descriptor for Agri - Horti Crops (Anon., NBPGR, 2007). Morphological data of twenty-nine forage and yield traits was collected. Average of the pooled data for the years 2004-05 and 2005-06 was analyzed using statistical software SPAR-1. Study of genetic variability, clustering pattern, correlation, path analysis of forage and grain yield, yield-attributing characters was performed. Results were analyzed.

The cluster analysis of pooled data recorded for the years 2004-05 and 2005-06 revealed that the evaluated genotype formed 12 clusters for 20 variables. The clustering pattern showed that, cluster number 5 was the biggest with 26 lines and cluster 4 was the smallest with only one line. The genotypes in cluster number 10 flowered most late having mean value of number of days for 50 per cent flowering as 70.50±9.19. Whereas, lines in cluster number 3 showed earliest flowering having mean value of number of days to 50 per cent flowering as 46.78±4.71. The lines having maximum total span of period to total flowering were grouped in cluster number 6 with maximum mean value of 93.29±6.08 DAS and lines with shortest total period of span to total flowering were grouped in cluster number 3 with minimum mean value of 63.22±7.56 DAS.

The tallest lines were clustered in cluster number 4 with maximum mean value of plant height of 205.72±0.0 cm and shortest genotypes were clustered in cluster number 8 with minimum mean value of 148.2±3.66 cm. Most leafy lines were grouped in cluster number 4 with mean value of 185.29±0.0 leaves per plant. The higher fodder yielding lines were grouped in cluster number 10 with maximum mean value of fresh biomass per plant being as 859.33±119.08 g and dry biomass per plant being as 580.07±64.26 g. The heaviest seed bearing lines with maximum mean value of 100 seed weight as 16.72±0.00 g were clustered in cluster number 4 and lightest seed bearing lines with minimum mean value of 100 seed weight as 11.84±2.46 g were clustered in cluster number 9. Late maturity initiation was observed in genotypes of cluster number 4 with maximum mean value of days to maturity initiation 116.00±0.0 DAS and genotypes with early maturity initiation were clustered in cluster number 3 with a minimum value 76.22±8.55 DAS. The genotypes with maximum span of days to total maturity were grouped in cluster number 6 with a maximum mean value of 138.87±6.22 DAS and lines with less span of pod maturity were grouped in cluster number 9 with a minimum mean value of 120.91±6.01 DAS. Maximum pod bearing lines were grouped in cluster 11 with a mean value of

44.70±5.38 pods per plant. The longest pod bearing lines were grouped in cluster number 4 with maximum pod length mean value 18.98±0.0 cm and shortest pod bearing lines were grouped in cluster number 9 with minimum mean value 12.31±2.25 cm.

The highest number of seeds/plant bearing genotypes was grouped in cluster number 11 with a mean value of 616.21±84.97 seeds/plant and lowest number of seeds per plant bearing genotypes was grouped in cluster number 2 with a mean value of 139.72±77.79 seeds per plant. The maximum distance between cluster centroids was between cluster 7 and 10 (11.781) followed by; between 9 and 10 (11.589); and between cluster 10 and 11 (11.054). Maximum average distance of cluster members from cluster centroids was 3.711 in case of cluster number 2.

A wide range of variation was observed for the various characters recorded. On averaging data of both years, genotypes EC-240884, NP-3-14-A and IL-182 showed good early seedling vigour. Genotypes IL-1177, IL-887 and IL-3168-B showed medium early seedling vigour. Twelve genotypes were of erect type, 53 genotypes were of semi erect type, 6 genotypes were of bushy type, 27 genotypes were of ainy type and 74 genotypes were of spreading type. The earliest flowering accessions were EC-240564 and EC-244979 in 38 DAS and most late flowering genotype was IL-181 in 88 DAS i.e. by 16th October 2004. In 2005, date of sowing was 25th July 2005 and days to 50 per cent flowering ranged from 39 to 87 DAS, the earliest flowering accession was EC-244217-1 in 39 DAS and most late genotype was IL-4216 in 87 DAS.

Tallest genotypes were, HY-10P-10-2-4 (234.9 cm) followed by IL-99-171 (231.7 cm) and Local-1 (231.2 cm) and shortest were IL-168 (105.9 cm) followed by NP-3-10 (113.0 cm) and HY 10P- 52-7 (115.3 cm). Accessions having more number of leaves per plant were [IL-1177 (201); IL-1057 (185); and IL-1050-3 (158)]. Higher biomass in gram was obtained for the accessions [IL-1177 (943.5); IL-3171 (775.1); and IL-966-B (663.7)]. Higher leaf/stem ratios were obtained for genotypes [HY6P52-3 (1.04); IL-893 (1.01); and IL-99-171 (0.95)]. Higher dry weight/ plant in gram was obtained for the accessions [IL-1177 (625.51); IL-3171 (543.63); and IL-449 (345.94)]. Accessions that showed higher dry Leaf/Stem ratio were [IL-160-A (1.02); IL-99-98-1 (0.97); and (IL-792 (0.94)]. Genotypes that had higher 100 seed weight in gram were [IL-181 (25.2); IL-4216 (22.6); and IL-156 (22.5)]. The genotypes that showed early maturity initiation in DAS were [NP-3-10 (60); EC-240782 (61); and EC-240887 (62)] and genotypes that showed late maturity initiation in DAS were [IL-390 (120); IL-853 (119); and IL-1155-B (118)]. Genotypes that took lesser number of days for total maturity of pod were [EC-244979 and IL 99-72 (113); EC-240884 and IL 99-65 (115); and EC

244310 (116)] and genotypes that took more number of days for total maturity of pod were [IL-892, IL 380-A and IL 622 (148); IL-853 (147); and EC 240998(146)]. The genotypes that showed higher number of pods per plant were [IL 3168A (53.2); IL156 (51.3); and IL2000-180 (50.5)]. Genotypes that had higher pod length in cm were [Local 1 (24.6); IL 2000-182 (24.4); and NP 3-7 (21.8)] and genotypes that had lower pod length in cm were [IL 792 (8.6); and IL 886 and IL 155 (9.2)]. Lines that showed higher number of seeds per pod were [Local-2 (22.2); Local-1 (21.1); and IL 1057 (20.8)]. Genotypes that showed higher number of seeds per plant were [EC 24102-1 (730.9); IL 3117 (725.4); and IL1177-B (720.5)].

The frequency distribution pattern of 29 traits from the pooled data of the years 2004-05 and 2005-06, varied from almost symmetrical to asymmetrical types in different cases. In general the pattern of distribution was of unimodal type. 110 germplasm lines were observed in medium group of early plant vigour i.e. at 25 DAS whose plant height ranged from 15.0 to 20.0 cm. Forty six genotypes were grouped in very good plant vigour group with plant height more than 20.0 cm. Maximum number (64) of genotypes had days to 50 per cent flowering ranging between 46 and 55 days. 41 germplasm lines flowered 50 per cent in days ranging between 56 and 65 days. 34 genotypes flowered 50 per cent on or before 45 days from the date of sowing.

Maximum number of 102 genotypes had days to total flowering between 56 to 75 days. 47 lines had days to total flowering between 76 to 95 days. 20 genotypes fully flowered in 96 to 115 days, while three genotypes fully flowered in less than 55 days from the date of sowing. Maximum number of genotypes (72) fell in 136 to 165 cm plant height class, 40 germplasm lines had plant height between 166 to 195 cm, and 36 genotypes had plant height between 106 to 135 cm. 21 genotypes had plant height between 195 to 225 cm, while three germplasm lines had plant height more than 225 cm. Maximum number (91) of genotypes had 21 to 70 leaves per plant. Seventy genotypes had 71 to 120 leaves per plant. Nine genotypes had 121 to 170 leaves per plant. Two genotypes had 171 to 220 leaves per plant. Maximum number of genotypes (103) having biomass per plant in between 281 and 455 g. Forty three genotypes had biomass per plant between 106 and 280g. Twenty two genotypes had biomass per plant in between 455 and 630g. Three genotypes had biomass per plant between 631 and 815 g. A single genotype had biomass per plant in between 816 and 990 g. maximum number of genotypes (86) had L/S ratio in between 0.6 and 0.7. Forty five genotypes were found having L/S ratio in between 0.8 and 0.9. Thirty two genotypes were found having L/S ratio in between 0.4 and 0.5. Six genotypes were found having L/S ratio between 1.0 and 1.1. Three genotypes

had L/S ratio in between 0.2 and 0.3. Maximum number of genotypes (108) had dry weight per plant from 61 to 180 g.

Fifty four genotypes were found having 181 to 300 g dry weight per plant. Eight genotypes had dry weight per plant in the range of 301 to 420 g. One genotype had dry weight per plant in between 421 and 540 g. A single genotype had dry weight per plant in between 541 and 660 g. Maximum number of genotypes (76) were having dry L/S ratio from 0.5 to 0.6. Fifty three genotypes had dry L/S ratio between 0.7 and 0.8. Twenty nine genotypes had L/S ratio in between 0.3 and 0.4. Thirteen genotypes had dry L/S ratio between 0.9 and 1.0. A single genotype had dry L/S ratio between 1.1 and 1.2. maximum number of genotypes (107) had 100 seed weight in the range 13 to 18 g. Forty one genotypes were found having 100 seed weight in the range 7 to 12 g. A single genotype had 100 seed weight in between 25 and 30 g. Maximum number of genotypes (88) were found having 61 to 80 days to maturity initiation. Forty two genotypes were found to have days to maturity initiation in between 81 and 100 days. Forty one genotypes had days to maturity initiation in between 101 and 120 days. While a single genotype had days to maturity initiation either equal to or less than 60 days. Maximum number of genotypes (73) had 6 to 15 pods per plant. Forty eight germplasm lines had 16 to 25 pods/ plant. Twenty four germplasm lines had 26 to 35 pods per plant. Seventeen genotypes had a total of 36 to 45 pods per plant., while five genotypes had 46 to 55 pods/plant. Another five genotypes had 6 to 15 pods per plant.

Maximum number (101) germplasm lines with pod length 11 to 15 cm. Fifty nine genotypes had pod length in between 16 and 20 cm. Eight genotypes had pod length in between 6 and 10 cm. Four germplasm lines had long pods in the range 21 to 25 cm. Maximum number of genotypes (85) were found having 13 to 16 seeds per pod. Fifty genotypes were found having 9 to 12 seeds per pod. Thirty one genotypes were found having 17 to 20 seeds per pod. Three genotypes were found having 21 to 24 seeds per pod. Three genotypes were also found having five to eight seeds per pod. Maximum number (74) genotypes had 31 to 180 seeds per plant. Forty eight genotypes had 181 to 330 seeds per plant. Twenty six genotypes had 331 to 480 seeds per plant. Seventeen genotypes had 481 to 630 seeds per plant. Seven germplasm lines had 631 to 780 seeds per plant.

The correlation was established among different traits of the evaluated germplasm for the pooled data of the years 2004 and 2005. The analysis revealed that Days to 50 per cent flowering had a high significant correlation with days to total flowering (0.6530**), number of secondary branches (0.2676**), number of leaves/plant

(0.3605**), stem weight/plant (0.2617**), dry stem weight/plant (0.3800**), dry weight/plant (0.2998*), days to maturity initiation (0.4560**) and days to total maturity (0.2154**). Days to 50 per cent flowering had a negative and highly significant correlation with leaf length (-0.2790**), leaf width (-0.3692**), leaf/stem ratio (-0.4085**), dry leaf stem ratio (-0.4119**), number of pods (-0.3138**) and number of seeds/plant (-0.3086**). Plant height had significant and a positive correlation with number of nodes (0.2092**), days to total maturity (-0.1828*), pod length (0.1828*) and seeds/pod (0.1529*). Number of leaves/plant showed a positive and highly significant correlation with leaf weight/plant (0.5661**), stem weight/plant (0.6325**), dry leaf weight/plant (0.5423**), dry stem weight/plant (0.6898**), biomass/plant (0.6454**), dry weight/plant (0.6907**), days to maturity initiation (0.3199**), days to total maturity (0.2141**) and a negative significant correlation with dry leaf/stem ratio (-0.1613*). Biomass/plant had a positive and highly significant correlation with dry weight/plant (0.8856**) and days to maturity initiation (0.2035**). Leaf/stem ratio had a positive and highly significant correlation with dry leaf/stem ratio (0.6176**), number of pods (0.3053**), seeds/plant (0.2528**) and number of clusters (0.1674*). Dry weight/plant had a high significant correlation with days to maturity initiation (0.3159**), days to total maturity (0.1588*) and a negative correlation with dry leaf stem ratio (-0.2000*). Dry leaf stem ratio had a highly significant negative correlation with days to maturity initiation (-0.2542**), seeds/pod (-0.1649*) and positive correlation with number of clusters (0.1874*) and number of pods (0.2034*). 100 seed weight had a high positive correlation with pod length (0.3526**), seeds/pod (01939*) and days to total maturity (0.1711*). Days to maturity initiation had high significant positive correlation with days to total maturity (0.2927**). Number of clusters/plant had highly significant positive correlation with number of pods (0.8520**), number of seeds/plant (0.8220**). Number of seeds/pod had a significant positive correlation with pod length (0.1884*) and number of seeds/pod (0.1564*). Number of pods/plant had a highly significant positive correlation with seeds/plant (0.9314**). Pod length had a highly significant positive correlation with number of seeds/pod (0.8029**) and number of seeds/plant (0.3801**). Number of seeds/pod had highly significant positive correlation with number of seeds/plant (0.3821**).

Three sets of path coefficient analysis were performed. It was used to ascertain the direct and indirect contribution of different characters towards biomass/plant, dry weight/plant and number of seeds/plant. When biomass /plant was kept as dependant variable it was found that low direct effect was shown by days to total flowering (0.1271),

number of nodes (0.1335) and plant height (0.1028), moderate direct effect was showed by number of secondary branches (0.2788) and stem girth (0.2842), and a high direct effect by leaves/plant (0.3251), whereas negative, low direct effect by days to 50 per cent flowering (-0.1905). Number of leaves/plant showed low indirect effect through days to total flower (0.1041), days to 50 per cent flowering (0.1172), number of nodes (0.1231), number of primary (0. 1516), secondary branches (0.1880) and stem girth (0.1633). Number of secondary branches also showed indirect and low effect through number of leaves/plant (0.1612) and number of primary branches (0.1061). Also stem girth showed indirect and low effect through number of leaves/plant (0.1428) and number of primary branches (0.1165). Days to 50 per cent flowering also showed negative indirect and low effect through days to total flower (-0.1244). When dry weight/plant was kept as dependent variable low direct effect was shown by length of main branch (0.1387), negative low direct effect was shown by number of primary branches (-0.1058). Moderate and direct affect on dry weight/plant was shown by number of secondary branches (0.2005), stem girth (0.2336) and very high direct effect by leaves/plant (0.4598). Indirect low affect by leaves/plant through days to 50 per cent flowering (0.1658), number of nodes (0.1741) and moderate indirect effect through number of primary (0.2144), secondary branches (0.2659) and stem girth (0.2310). Indirect low effect was also shown by number of secondary branches (0.1160) and stem girth (0.1174) through number of leaves/plant. When the number of seeds/plant was dependent variable it was found that very high direct affect was shown by seeds/pod (0.3059), number of pods (0.9059) on seeds/plant. Indirect low effect was shown by number of pods through leaf length (0.1148), leaf width (0.1219) and pod length (0.1213). Indirect moderate effect was shown by seeds/pod through pod length (0.2456). Indirect moderate effect was also shown by number of pods through leaf/stem ratio (0.2765) and number of clusters (0.7718) and negative low effect through days to maturity initiation (-0.1158), days to total flower (-0.1848), moderate through days to 50 per cent flowering (-0.2843) and number of secondary branches (-0.2501).

Cytological study of pollen mother cells was conducted using rapid squash technique (Dyer, 1963). The metaphase plate, anaphase and diakinesis stages were observed in four accessions of cultigroups *unguiculata* (IL-1177 and EC548999); *sesquipedalis* (EC548875); and *cylindrical* (IC438864). The size of the chromosomes was found to be very small therefore the study was restricted to only a few accessions. In cultigroup *cylindrical* (1 accession), characteristic tetrads were observed. Maximum percent pollen fertility was shown by accessions of cultigroup *sesquipedalis* i.e. EC

548873 with 96 per cent, followed by EC 548867 with 95 per cent fertile pollens. Minimum percent pollen fertility was shown by line IVM-1 of cultigroup *unguiculata* with 80 per cent fertile pollens.

Chromosome associations were noted during diakinesis, metaphase and anaphase in few accessions of three cultigroups of cowpea i.e. *unguiculata*, *sesquipedalis* and *cylindrical*. All the accessions showed a uniform chromosome number of 2n=22. Chromosome associations varied from cell to cell both between and within different accessions. Five different types of associations were observed in *sesquipedalis* cultigroup accession EC548873, four types of associations in cultigroup *cylindrical* accession IC438864, six types of associations were observed in *unguiculata* cultigroup accession EC548999 with arrow shaped leaves and four types were observed in *V. unguiculata* cultigroup accession IL-1177 with normal leaves.

The pooled data including 60 cells involving 1320 chromosomes showed that maximum i.e. 25 per cent cells were associated as 11 bivalents followed by 9II+4I and 1IV+8II+2I associations which were visualized in 20 per cent cells each, respectively. Chromosomal associations 1IV+7II+4I and 10II+2I were observed in 15 per cent and 16.66 per cent cells respectively. The minimum association per cell was observed to be 2IV+7 II and was visualized in 3.33 per cent cells. Configurations of more than 4 chromosomes have not been observed, indicating that there is little if any role of gross structural changes in the evolution of different species. However, the occurrence of multivalent/univalent configurations in meiotic system is an indicator of hybridity involved in the origin of different cultigroups.

The isozyme analysis of thirty six germplasm lines was performed on poly acrylamide gel for Esterase, Peroxidase, Polyphenyl peroxidase and SDS PAGE as per standard procedures (Markert, 1959). Thirty six lines included six of cultigroup *sesquipedalis*, three of *cylindrical* or *catjang* two of *pubescence*, and twenty five of *unguiculata*. No cultigroup specific bands were observed but different lines were characterized.

Esterase banding pattern showed presence of ten bands of Rm values 0.01 to 0.52. Eight bands were found to be polymorphic except bands 3 and 7 which were present in higher frequency being recorded in all the 36 genotypes. Band number 1 was least frequent and was prominently present in accession EC548867 of cultigroup *sesquipedalis* and absent in rest. Band 4 was prominent in the accession EC 548850 of *unguiculata*. Band number 9 was prominent in all genotypes except EC 548999 of cultigroup

unguiculata. The difference in intensity of the bands indicates quantitative variation for this enzyme.

PPO isozyme banding pattern indicated diversity among the lines. Banding pattern showed presence of 8 bands of Rm values 0.02 to 0.40. Three bands were found to be polymorphic. Bands numbers 1, 2 and 3 were present in higher frequency being recorded in all the 36 lines. The banding pattern of peroxidase revealed nine bands in total of Rm values 0.01 to 0.35. Bands number 1, 2, 3 and 5 were the most frequent. Band 1, 2, 3, 4, 5 and 9 were prominent in Hy6p 52-10 line of cultigroup *unguiculata*. Band 3 was also prominent in genotype IL-156 of cultigroup *unguiculata* showing differential activity. The banding pattern of SDS revealed 9 bands of Rm values 0.01 – 0.56. The SDS banding pattern revealed polymorphism for all the 9 bands and diversity was observed. SDS Profile of accessions IC-438865, EC-548873, EC-548866 and EC-548867 were similar with all the nine bands present. Bands 3, 4, 5 and 9 were present in accessions i.e. EC 548878 and EC 548875 whereas bands 2, 6 and 7 were absent in these accessions. Thus the above lines are characterized at biochemical level by better tools which establish uniqueness and identities of individual and cultivars for further utilization.

Six bio-chemical seed tests *viz.* peroxidase enzyme test, KOH bleach test, NaoH test (Chemlar and Mostovoj, 1938), GA3 growth response test (Payne, 1976), fluorescence test (Grabe, 1957) and modified phenol tests were performed for effective distinction of thirty six germplasm lines of cowpea. Peroxidase test revealed that Lines EC-548875, IL-1063, EC-548851, IL-3178, RAJL-16, IC-438865, IL-2000-184, NP-3-14-A, IL-1177, IL-99-34, NP-3-14-B, IL-156, RAJL-2, IL-1170-A, EC-548873 showed a positive reaction with red colour change. Lines EC-548999, EC-548878, HY6P52-10, EC-24102-1, EC244236, IL-160-B, IL-390, IC-438864, RAJL2, EC-240884, EC-548850, EC-240564, EC-548861, IL-99-72, IVM-1, IL-3152-1, EC-548864, EC-548865, IL-131, EC548866 and EC 548867 showed a negative reaction with no colour change. NaOH test showed that Lines EC548999, EC548878, HY6P52-10, EC-24102-1, EC-244236, IL-1063, EC-548851, IL-3178, IL-390, RAJ-2, NP-3-14-B, RAJL-2, IL-99-72, IL-1170-A, IVM-1, IL-3152-1, EC548864 showed positive reaction with red colour change. Lines EC548875, IL-160-B, RAJL-16, IC-438864, IC-438865, IL-2000-184, IL-99-34, EC-548850, EC-240564, IL-156, EC-548864, EC-548865, IL-131, EC-548873, EC-548866, EC-548867 showed a negative reaction with no colour change. KOH bleach test showed that accession EC244236 had positive reaction i.e. bleached seed coat colour whereas rest all the lines showed a negative reaction with no colour change. Phenol colour test showed

that accession EC-24102-1 showed black tip and line RAJ-2 showed black colour change of seed coat. Rest other lines did not show any colour change. Fluorescence test showed that all the lines showed florescence except lines NP-3-14-A, IL-156, RAJL-2, IL-99-72, IL-1170-A, IL-3152-1, EC-548873, EC-548866 and EC548867. GA_3 growth test showed that lines EC548999, HY6P-52-10, IL-1063, IL-160-B, IL-31-78, RAJ-2, IL-2000-184, NP-3-14-A, IL-1177, EC548861, NP-3-14-B, RAJL-2, EC-548864, EC548865 and IL-131 showed high response for both dry weight and seedling weight. Whereas lines EC-548878, EC-24102-1, EC-548875, EC-244236, EC-548851, IL-390, RAJL-16, IC438864, IC438865, IL-99-72, EC-548873, EC-548866 and EC-548867 showed low response for both dry weight and seedling weight. Lines EC-240884, IL-99-34, EC-548850, IL-1170-A and IVM-1 showed a high response for only seedling weight. Lines EC 240564 and IL-3152-1 showed high response for dry weight by low response of seedling weight. Line IL-156 showed a low response for seedling weight.

Morphological evaluation of 172 cowpea germplasm (including three cultigroups *i.e. unguiculata, catjang* and *sesquipedalis*) facilitates identification of promising donor sources. The traits revealed by the study were well defined and useful for utilization in breeding of crop for any specific purpose. In this study the prime factors of concern were forage and grain production. So, the traits identified for these factors are discussed as following.

Identification of donor sources in respect of forage were; higher biomass/plant (g) for the accessions [IL-1177 (943.5); IL-3171 (775.1); and IL-966-B (663.7)] and higher fresh leaf/stem ratios for genotypes [HY6P52-3 (1.04); IL-893 (1.01); and IL-99-171 (0.95)]. In case of dry matter yield (g/plant), accessions [IL-1177 (625.51); IL-3171 (543.63); and IL-449 (345.94)] were high yielding. Accessions that showed higher dry Leaf/Stem ratio were [IL-160-A (1.02); IL-99-98-1 (0.97); and (IL-792 (0.94)]. The cluster analysis of pooled data for 04-05 and 05-06 years grouped the higher fodder yielding lines in cluster number 10 i.e. IL-3171 and IL-1177 with a maximum mean value of fresh biomass per plant, 859.33 ± 119.08 g and dry biomass/plant 580.07 ± 64.26 g. Earlier flowering lines identified were EC-240564 and EC-244979 showing 50 per cent flowering in 38 days after sowing and can be harvested quickly i.e. in 38 days after sowing for green fodder.

Identification of donor sources in respect of grain and grain yield were; early maturity initiation (76 DAS) by, EC240887, HY6P 52-3, HY-10P58-3, EC120001, EC240714, NP-3-10, HY5P, HY-5P-6S-215, EC-240800, EC-244217-1, HY-5p-32-2b, IL-55-1, IL-15-1, IL-132, IL-160, IL-2000-184, IL-419-2, IL-1086-2 and IL-887

The heaviest seed bearing lines identified with 100 seed weight were IL-181 (25.2g); IL-4216 (22.6g); and IL-156 (22.5g).

The lines with higher number of pod clusters/plant were IL-178-4, IL-622, IL-362, IL-812-1, IL-867, IL-380B, IL-893-1, IL-216-1, IL-160-11, IL-1721 with a mean value of 15 pod clusters/plant.

The maximum pod bearing lines identified were IL-90, EC-240809, IL 3117, IL-155-1, IL-3168-A, IL-200-180, IL-160-9, IL-156, IL-1182, IL-14177-A, IL-1156-1, IL-1177-B, EC-24102-1) with a mean value of 45 pods per plant Longest pod bearing lines identified were Local 1 (24.6 cm); IL 2000-182 (24.4 cm); and NP 3-7 (21.8 cm). Highest numbers of seeds/pod bearing lines were Local-2 (22); Local-1 and IL 1057 (21). The highest numbers of seeds per plant bearing lines were IL-90, EC-240809, IL 3117, IL-155-1, IL-3168-A, IL-200-180, IL-160-9, IL-156, IL-1182, IL-14177-A, IL-1156-1, IL-1177-B and EC-24102-1 with a mean value of 616 seeds / plant.

Use of studied morphological, physiological and biochemical traits was done for the identification of donor sources of early maturity, erect plant habit, less days to 50 per cent flowering, higher fodder yield, more leafy lines, higher leaf/stem ratio, higher number of pod bearing, longer pod bearing and more seed/plant bearing lines. This can be utilized in further breeding programmes. Some of these lines have also been characterized at biochemical level by isozyme analysis and chemical seed tests for establishing their uniqueness and identities. Chromosomal associations have also been studied of the higher fodder yielding line.

The conclusion of study with respect to hypothesis included, collection of all the germplasm with favourable traits in reference to forage yield and cropping of cowpea on one platform for further utilization for developing varieties having traits of early maturity, determinate growth habit and high forage and grain yield. With the introduction of plant variety Protection Act under GATT, the need for precise genotypic characterization with clear Distinctness (D), Uniformity (U) and Stability

(S) have been addressed in this work. The biometrical analysis of evaluated germplasm made possible the following.

a) Assessment of genetic variability in the germplasm

b) Selection of elite accessions from the germplasm

c) Choice of parents for hybridization.

The cytological and biochemical characterization of representative genotypes were established from similar groups within the germplasm.

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Appendix A

Table A.1 Morphological traits recorded for evaluated germplasm lines during the year 2004-05

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➤	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	Hy10-36-4	1	1	46.0	59.0	199.58	165.25	28.85	7.50	2.90	2.00	121.23	15.25	12.56	335.66	406.81	177.01	293.90	742.47	0.83	470.91	0.60	15.04	74.0	120.0	8.16	16.32	16.46	11.79	192.49
2	EC-48720	2	2	44.0	74.0	188.47	181.28	21.41	6.56	15.92	1.80	209.00	12.14	10.50	301.72	463.76	132.27	341.16	765.48	0.65	473.43	0.39	11.80	82.0	130.0	2.04	8.16	13.52	11.79	96.25
3	IVM-1	2	1	76.0	90.0	138.82	133.02	26.99	7.50	2.90	2.04	107.03	13.60	9.78	143.10	290.96	59.04	166.52	434.06	0.49	225.56	0.35	13.41	102.0	132.0	4.08	13.99	14.46	10.81	151.24
4	EC-244310	2	4	41.0	90.0	124.59	132.05	19.54	8.43	13.00	1.60	120.13	10.10	8.86	103.47	295.23	51.19	195.26	398.70	0.35	246.45	0.26	6.69	111.0	120.0	3.06	5.83	11.76	8.84	51.56
5	EC-240564	2	5	39.0	59.0	142.36	176.33	30.71	8.43	13.00	2.00	80.82	14.09	12.87	193.08	324.63	68.75	198.48	517.71	0.59	267.23	0.35	14.94	74.0	111.0	3.06	10.49	15.40	7.86	82.50
6	EC-244979	2	5	39.0	59.0	165.01	198.07	21.41	5.62	1.45	1.20	83.00	12.63	9.58	194.83	212.30	69.59	130.44	407.13	0.92	200.03	0.53	12.09	72.0	121.0	4.08	11.66	14.70	10.81	126.04
7	EC-240887	3	5	42.0	47.0	109.39	203.91	18.61	6.56	2.90	1.30	95.02	13.41	10.19	150.02	330.85	57.54	239.49	480.87	0.45	297.04	0.24	13.96	60.0	129.0	7.14	33.81	16.46	15.72	531.64
8	HY10P527	2	2	46.0	60.0	111.49	179.92	15.82	3.75	1.45	1.10	58.97	11.46	9.37	62.08	137.55	35.59	66.85	199.63	0.45	102.44	0.53	7.77	72.0	131.0	3.06	9.33	10.70	13.76	128.33
9	HY6P52-3	2	5	47.0	60.0	170.25	129.43	20.48	5.62	4.34	1.20	95.02	12.82	10.19	189.66	183.65	55.77	66.45	373.31	1.03	122.22	0.84	10.13	71.0	130.0	2.04	19.82	13.64	12.77	253.22
10	EC-240884	3	5	42.0	65.0	150.17	77.29	16.75	4.69	2.90	1.20	50.24	13.79	9.58	141.34	202.48	53.62	76.34	343.82	0.70	129.96	0.70	14.94	80.0	110.0	4.08	12.83	14.11	11.79	151.24
11	EC-244236	2	5	49.0	60.0	137.33	130.69	16.75	7.50	7.24	1.30	161.63	10.10	8.55	147.96	222.60	70.43	95.64	370.57	0.66	166.07	0.74	13.86	91.0	121.0	6.12	9.33	13.29	10.81	100.83
12	NP-3-14-A	3	5	45.0	58.0	134.45	142.73	15.00	4.69	1.45	1.87	58.97	13.73	10.40	156.86	250.43	66.41	104.49	407.29	0.63	170.91	0.64	12.98	71.0	129.0	4.08	8.16	11.88	8.84	72.18
13	HY6P52-10	2	5	42.0	55.0	140.82	161.18	16.75	4.69	2.90	1.80	50.24	13.02	10.09	112.06	170.01	55.67	73.04	282.07	0.66	128.72	0.76	14.35	69.0	111.0	7.14	20.99	15.29	9.83	206.24
14	HY6P52-9	3	5	70.0	74.0	138.29	158.17	24.20	7.50	14.48	1.50	151.81	11.56	9.78	167.21	396.33	82.01	149.39	563.53	0.42	231.40	0.55	14.94	82.0	125.0	1.02	3.50	14.11	10.81	37.81
15	HY-10P583	3	5	47.0	60.0	134.10	134.96	17.68	6.56	7.24	1.70	169.00	13.60	9.99	256.92	366.37	103.03	176.07	623.29	0.70	279.10	0.59	12.19	71.0	118.0	2.04	22.15	13.64	14.74	326.55
16	EC120001	3	5	42.0	55.0	152.17	118.46	17.68	4.69	1.45	2.10	98.00	14.86	11.43	222.46	255.07	91.35	115.80	477.53	0.87	207.16	0.79	14.06	80.0	111.0	3.06	12.83	16.81	13.76	176.45
17	EC241023	3	5	72.0	74.0	137.94	179.62	19.54	7.50	17.37	1.60	191.12	12.43	9.99	225.57	348.75	101.35	192.88	574.31	0.65	294.23	0.53	13.86	80.0	129.0	1.02	8.16	18.81	12.77	104.27
18	EC244223-1	2	5	47.0	60.0	197.31	197.68	16.75	4.69	5.79	1.40	78.63	12.53	10.71	175.90	271.76	75.38	125.41	447.66	0.65	200.79	0.60	10.52	71.0	121.0	6.12	7.00	14.46	10.81	75.62
19	NP-3-7	2	2	53.0	60.0	167.89	137.87	22.34	5.62	5.79	1.30	109.21	14.77	10.40	295.92	380.28	167.30	231.82	676.21	0.78	399.12	0.72	20.25	71.0	120.0	7.14	16.32	22.10	11.79	192.49
20	EC-240714	2	2	45.0	56.0	66.88	115.83	12.10	4.69	2.90	1.30	58.97	13.02	10.09	129.34	207.11	55.95	93.64	336.45	0.62	149.60	0.60	15.14	70.0	120.0	12.23	20.99	20.69	15.72	329.98
21	EC-244243	2	5	76.0	90.0	113.50	132.63	19.54	6.56	8.69	2.10	163.82	11.27	10.19	177.55	371.01	94.90	260.50	548.56	0.48	355.41	0.36	13.57	95.0	122.0	11.21	24.49	14.34	13.76	336.86
22	EC-240840	2	5	76.0	90.0	197.31	215.55	24.20	4.69	7.24	1.90	103.75	11.46	9.68	65.50	239.58	50.63	173.47	305.07	0.27	224.10	0.29	13.47	91.0	112.0	9.18	23.32	14.11	14.74	343.73
23	NP-3-10	2	2	42.0	45.0	125.98	111.27	17.68	6.56	5.79	1.50	121.23	13.41	10.61	279.37	340.03	101.16	134.20	619.40	0.82	235.36	0.75	15.73	59.0	111.0	3.06	5.83	10.58	14.74	85.93
24	EC-244249	2	5	47.0	60.0	179.85	179.63	13.96	2.81	1.45	1.10	53.51	13.02	9.89	120.05	168.44	62.40	100.82	288.49	0.71	163.22	0.62	13.96	71.0	122.0	3.06	12.83	17.64	13.76	176.45
25	HY-5P-6S-215	2	5	42.0	50.0	142.30	170.63	17.20	6.29	3.19	1.43	68.08	14.14	10.54	193.98	263.58	117.10	122.25	457.56	0.74	239.36	0.96	17.33	62.0	129.0	11.38	19.29	13.88	12.76	246.26
26	EC-244217	2	2	43.0	45.0	162.83	145.39	22.26	8.39	10.65	1.28	185.77	11.72	9.65	202.07	370.51	111.44	226.71	572.58	0.55	338.15	0.49	18.99	85.0	129.0	5.17	7.89	9.92	11.70	92.35
27	IVM	2	1	83.0	102.0	165.63	126.29	25.29	7.34	3.19	1.62	144.92	8.23	7.16	112.26	239.39	59.29	186.79	351.65	0.47	246.08	0.32	16.78	108.0	122.0	4.14	7.02	13.09	14.89	104.47
28	EC-240998	2	2	73.0	75.0	199.80	211.15	23.27	6.29	6.39	1.43	114.77	10.65	8.16	112.26	338.72	68.64	194.89	450.98	0.33	263.53	0.35	13.58	85.0	131.0	3.10	5.26	10.91	11.70	61.56
29	EC-240650	2	2	42.0	55.0	143.00	166.51	18.21	5.24	3.19	1.05	78.76	12.01	9.05	169.11	245.19	95.52	102.10	414.29	0.69	197.62	0.94	15.57	69.0	129.0	4.14	10.52	10.91	11.70	123.13
30	RA-2	3	4	83.0	102.0	157.81	132.72	26.30	7.34	6.39	1.43	193.55	7.46	6.47	149.71	301.93	88.44	269.13	451.64	0.50	357.56	0.33	9.05	114.0	129.0	8.28	15.78	10.02	11.70	184.69
31	EC-240999	3	5	83.0	102.0	167.61	156.55	24.28	6.29	5.32	1.05	78.78	4.94	3.78	64.39	237.55	34.42	179.90	301.94	0.27	214.33	0.19	12.81	114.0	129.0	6.21	5.26	15.17	12.76	67.16
32	UPC-870	2	5	72.0	75.0	201.44	168.92	23.27	8.39	4.26	1.24	78.78	10.94	9.25	106.24	269.74	63.46	134.78	375.98	0.39	198.24	0.47	13.47	85.0	129.0	8.28	7.02	13.88	14.89	104.47
33	HY-10-P-10-2-4	3	5	72.0	75.0	254.63	195.77	18.00	8.39	6.39	1.34	99.21	12.98	8.16	156.24	300.46	70.76	198.89	456.70	0.52	269.65	0.36	21.31	85.0	127.0	10.35	15.78	12.99	12.76	201.48
34	RAJL-4	2	5	47.0	60.0	204.47	106.58	18.21	2.00	2.13	0.76	61.28	12.78	7.38	61.34	85.81	35.28	43.78	147.14	0.71	79.06	0.81	9.05	74.0	131.0	6.21	16.66	11.50	9.57	159.51
35	NP-3-8	2	5	69.0	75.0	212.29	162.89	22.00	8.39	8.52	1.34	77.81	11.14	8.06	65.83	245.28	38.11	141.28	311.11	0.27	179.40	0.27	15.57	85.0	119.0	3.10	1.75	9.62	10.64	18.66
36	EC-240800	3	5	42.0	61.0	180.79	140.77	18.21	7.34	3.19	1.43	84.62	12.98	9.65	170.63	305.06	81.73	155.97	475.69	0.56	237.70	0.52	15.68	72.0	132.0	11.38	25.43	13.98	12.76	324.61
37	EC-240740	3	5	44.0	61.0	138.45	115.63	17.20	5.24	3.19	1.43	65.17	11.91	8.65	110.73	159.38	52.12	105.81	270.11	0.69	157.93	0.49	17.22	74.0	124.0	4.14	17.54	12.89	11.70	205.21
38	EC-244217-1	2	5	47.0	61.0	197.94	141.77	20.23	6.29	4.26	1.81	69.06	15.40	10.35	140.73	286.66	56.29	195.56	427.39	0.49	251.84	0.29	12.92	76.0	128.0	10.35	27.18	11.90	15.96	433.75
39	NP-3-14-B	3	5	51.0	61.0	249.61	201.40	21.25	5.24	4.26	1.24	96.29	14.24	11.74	196.05	329.52	85.18	150.22	525.57	0.59	235.41	0.57	15.68	74.0	131.0	6.21	15.78	13.98	12.76	201.48
40	EC-240842	2	5	83.0	102.0	186.97	99.84	13.15	3.00	2.13	0.76	32.10	7.75	6.17	23.98	73.57	13.56	60.51	97.55	0.33	74.08	0.22	19.98	108.0	150.0	5.17	4.38	13.98	14.89	65.30
41	Local-3	2	5	40.0	61.0	234.00	192.75	17.20	6.29	9.58	1.34	153.68	12.78	8.75	206.56	315.72	128.82	173.74	522.28	0.65	302.56	0.74	17.88	72.0	132.0	11.38	18.41	12.00	8.51	156.71
42	Local-2	2	5	68.0	75.0	294.00	115.63	18.92	6.29	2.13	0.86	27.23	12.30	8.95	38.69	140.07	23.82	84.57	178.95	0.28	108.39	0.28	14.02	89.0	132.0	8.28	12.28	21.52	22.34	274.24
43	Local-1	2	5	45.0	61.0	281.10	118.95	14.16	4.20	1.06	0.95	42.80	13.75	8.36	89.81	125.72	45.47	61.73	215.53	0.71	107.19	0.74	15.57	74.0	116.0	7.24	7.02	24.00	21.27	149.25
44	NP-3-7-1	3	5	51.0	61.0	233.28	178.98	26.30	5.24	2.13	1.34	80.73	13.95	10.15	157.16	315.72	71.33	113.35	472.89	0.50	184.69	0.63	13.58	72.0	118.0	6.21	16.66	14.97	12.76	212.68
45	HY-5p-32-2b	2	5	42.0	65.0	197.47	123.37	15.18	6.29	4.26	1.34	66.14	12.20	9.95	152.67	262.11	77.78	118.97	414.78	0.58	196.76	0.65	14.57	81.0	129.0	3.10	12.28	14.08	17.02	208.95

Highlights: : Higher values; : Lower values

Table A.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table A.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
-	Trait No.>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
46	EC-24077	2	5	70.0	75.0	232.42	238.60	30.35	7.34	10.65	1.62	142.98	10.65	8.26	131.75	409.26	70.86	227.58	541.00	0.32	298.44	0.31	15.57	82.0	151.0	2.07	7.02	13.98	14.89	104.47
47	NP-652-Y	3	5	51.0	61.0	289.27	230.96	24.28	5.24	1.06	1.34	70.03	14.53	10.25	160.13	297.06	67.73	102.59	457.18	0.54	170.32	0.66	15.68	71.0	128.0	8.28	12.28	12.00	12.76	156.71
48	IL-99-69	2	5	51.0	61.0	207.62	204.82	21.25	9.44	6.39	2.36	157.57	13.46	10.25	276.88	409.26	100.97	177.21	686.13	0.68	278.18	0.57	11.15	72.0	131.0	13.45	30.69	11.60	12.76	391.77
49	EC-241037	1	5	82.0	102.0	221.15	184.59	25.40	4.64	8.21	1.92	229.15	9.80	7.22	206.45	443.17	160.60	304.84	649.61	0.47	465.44	0.53	14.09	111.0	150.0	2.70	2.31	13.73	12.86	29.75
50	EC240896	2	5	53.0	66.0	158.58	121.54	18.56	5.57	6.16	1.21	96.54	12.40	8.26	132.48	250.44	86.39	105.48	382.93	0.53	191.87	0.82	18.22	82.0	131.0	2.70	7.71	10.89	10.88	83.90
51	HY-6P-05-28	2	5	51.0	64.0	123.99	134.00	18.56	7.43	6.16	1.51	95.48	12.30	8.45	127.86	311.62	88.37	126.16	439.48	0.41	214.54	0.70	13.18	72.0	150.0	2.70	6.94	13.73	12.86	89.24
52	EC-240782	3	5	45.0	58.0	201.97	184.59	21.49	3.72	3.08	1.41	65.77	12.40	9.97	141.73	235.96	91.07	105.93	377.69	0.60	197.00	0.86	16.27	61.0	150.0	3.60	5.40	12.85	13.85	74.74
53	IL-181	2	5	88.0	103.0	177.45	135.35	19.54	6.50	3.08	1.21	98.66	14.00	9.97	203.39	290.00	105.74	126.01	493.40	0.70	231.75	0.84	24.75	72.0	120.0	3.60	7.71	11.87	6.93	53.39
54	IL-792	2	1	51.0	61.0	152.71	128.08	21.49	5.57	2.05	1.41	85.93	12.00	8.45	161.79	299.08	92.76	120.10	460.87	0.54	212.86	0.77	7.91	72.0	120.0	9.89	14.65	8.14	9.89	144.91
55	IL-179	3	1	51.0	61.0	153.76	176.91	16.61	4.64	5.13	1.11	80.63	11.40	7.88	89.40	176.51	49.95	93.54	265.91	0.51	143.49	0.53	9.40	75.0	130.0	13.48	26.98	8.83	9.89	266.94
56	IL-90	3	1	53.0	61.0	133.84	94.22	19.54	4.64	2.05	1.41	101.84	12.90	8.83	138.68	214.34	82.28	100.04	353.02	0.65	182.33	0.82	11.11	75.0	131.0	18.88	38.55	9.90	9.89	381.35
57	IL-178-8	2	3	51.0	62.0	106.17	159.25	22.47	6.50	5.13	1.21	91.23	12.50	8.83	149.49	254.01	48.69	111.61	403.51	0.59	160.30	0.44	18.56	76.0	131.0	3.60	3.08	10.79	8.90	27.46
58	EC-240809	2	3	51.0	62.0	143.91	178.98	21.49	5.57	2.05	1.31	81.69	13.40	10.06	150.97	284.60	85.58	114.95	435.57	0.53	200.54	0.74	13.86	72.0	131.0	17.08	32.38	16.38	15.83	512.53
59	IL-55-1	3	4	51.0	62.0	140.45	102.84	14.66	3.72	2.05	1.21	33.95	12.00	8.83	67.77	118.90	27.88	55.66	186.67	0.57	83.54	0.50	15.35	75.0	142.0	7.19	8.48	13.93	16.82	142.62
60	IL-177	2	4	51.0	62.0	263.81	160.70	20.52	3.72	3.08	1.01	48.80	13.10	9.21	52.42	106.25	23.31	51.88	158.67	0.49	75.19	0.45	17.30	76.0	140.0	6.29	14.65	14.71	14.84	217.37
61	RAJ-2	3	1	53.0	62.0	166.56	154.02	19.54	3.72	3.08	1.11	57.00	11.60	8.64	57.04	109.93	38.61	47.84	166.97	0.52	86.46	0.81	7.91	72.0	121.0	3.60	13.88	10.89	10.88	151.01
62	IL-99-40	3	1	51.0	79.0	207.21	155.82	16.61	2.00	2.05	1.11	37.13	14.00	10.63	50.85	99.12	32.91	48.91	149.97	0.51	81.82	0.67	10.89	72.0	122.0	8.09	18.50	12.75	11.87	219.66
63	IL-99-38	3	1	51.0	62.0	166.34	208.07	15.63	2.79	3.08	1.11	41.37	11.20	9.49	56.23	109.93	41.02	48.00	166.15	0.51	89.02	0.85	10.89	75.0	121.0	6.29	16.19	10.79	8.90	144.15
64	IL-99-34	2	1	51.0	62.0	141.08	165.17	23.45	3.72	3.08	1.11	75.32	14.30	6.17	66.37	119.98	40.67	64.54	186.35	0.55	105.21	0.63	10.89	75.0	121.0	6.29	16.19	10.79	8.90	144.15
65	IL-99-98-1	3	4	51.0	62.0	178.91	136.08	20.52	4.64	4.10	1.01	91.23	13.00	9.02	177.23	221.58	129.55	105.60	398.81	0.80	235.16	1.23	13.41	73.0	126.0	3.60	8.48	10.79	10.88	92.29
66	IL-99-98	3	4	61.0	68.0	151.66	178.67	16.61	3.72	3.08	1.01	59.41	10.90	8.35	52.42	97.28	41.55	58.34	149.70	0.54	99.89	0.71	9.40	74.0	119.0	4.49	6.94	10.98	10.88	75.51
67	IL-99-73	3	4	51.0	68.0	165.92	97.33	17.59	4.64	3.08	1.21	79.56	14.50	10.44	89.40	149.49	59.84	77.13	238.89	0.60	136.97	0.78	11.57	76.0	119.0	5.39	12.33	11.28	10.88	134.23
68	IL-99-2	3	4	53.0	62.0	206.79	124.34	22.47	4.64	5.13	1.31	95.48	13.80	9.59	123.24	230.55	81.68	128.46	353.79	0.53	210.14	0.64	11.11	77.0	118.0	6.29	19.27	10.00	7.91	152.54
69	IL-99-72	3	4	51.0	62.0	210.97	105.65	17.59	3.72	3.08	1.21	33.95	14.00	11.20	60.09	133.27	37.92	59.93	193.37	0.45	97.86	0.63	7.45	76.0	112.0	5.39	32.38	11.77	10.88	352.37
70	IL-99-65	2	4	51.0	62.0	201.55	133.69	19.54	2.79	2.05	1.11	42.43	13.30	9.68	67.77	176.51	54.80	64.60	244.28	0.38	119.40	0.85	8.94	76.0	118.0	6.29	22.36	9.51	7.91	176.95
71	IL-01-88	2	5	47.0	60.0	180.28	136.39	15.63	7.43	5.13	1.41	77.44	13.00	6.65	132.48	290.00	52.51	104.88	422.49	0.46	157.39	0.50	14.09	73.0	151.0	4.49	4.63	11.18	8.90	41.19
72	IL-99-171	3	5	51.0	64.0	274.92	176.87	20.52	5.57	3.08	1.11	54.10	16.41	11.20	106.32	196.40	59.54	76.80	302.72	0.54	136.33	0.78	11.92	78.0	112.0	9.89	23.90	12.85	14.84	354.65
73	IL-3117	1	2	51.0	63.0	155.61	155.68	24.83	7.35	3.10	1.27	93.93	11.24	9.38	176.93	256.46	92.51	134.72	433.39	0.69	227.23	0.69	17.71	77.0	130.0	16.57	44.57	12.64	16.42	732.03
74	IL-15-1	2	2	45.0	58.0	165.49	196.93	19.66	8.40	3.10	1.27	95.01	12.79	9.28	259.87	303.20	115.70	165.52	562.87	0.86	281.21	0.70	13.50	72.0	160.0	9.67	16.34	12.84	16.42	268.41
75	IL-155-1	1	2	51.0	64.0	193.09	161.67	22.76	7.35	1.03	1.37	84.22	12.40	7.36	191.02	314.52	142.66	143.85	505.54	0.61	286.51	0.99	12.75	71.0	120.0	30.38	59.00	11.85	10.63	627.01
76	IL-3168-A	2	2	51.0	64.0	170.04	62.29	18.62	7.35	2.07	1.37	129.56	13.27	7.77	201.54	261.29	92.49	129.40	462.83	0.77	221.89	0.71	12.85	78.0	120.0	27.62	65.37	13.83	8.70	568.40
77	IL-160-B	2	5	51.0	64.0	153.00	172.78	17.59	7.35	4.14	1.57	75.58	11.43	8.07	126.16	198.39	67.82	124.50	324.55	0.64	192.32	0.54	13.72	77.0	112.0	6.90	16.34	11.85	10.63	173.68
78	IL-886	2	2	42.0	55.0	147.32	137.52	18.62	8.40	4.14	1.57	89.61	11.04	7.97	140.14	235.46	59.62	105.27	375.59	0.60	164.89	0.57	16.09	70.0	131.0	1.38	4.46	8.89	7.73	34.45
79	IL-132	2	2	51.0	63.0	173.44	152.48	18.62	6.30	4.14	1.47	114.45	12.11	9.08	161.16	258.10	81.23	123.34	419.27	0.62	204.57	0.66	17.07	77.0	134.0	5.52	8.91	15.11	14.49	129.18
80	IL-160	3	2	51.0	64.0	184.80	179.51	17.59	9.46	2.07	1.47	82.06	13.18	9.18	224.24	350.04	119.54	193.42	574.28	0.64	312.96	0.62	15.77	78.0	132.0	5.52	17.83	13.63	13.53	241.14
81	IL-1155-B	2	2	82.0	103.0	200.25	212.63	22.76	5.25	9.31	1.08	206.22	8.23	7.56	178.26	424.17	75.21	362.51	602.43	0.42	437.72	0.21	13.29	112.0	150.0	5.52	13.37	15.80	13.53	180.65
82	IL-956	3	5	51.0	63.0	165.14	167.01	22.76	8.40	3.10	1.18	64.78	11.53	9.28	75.38	201.58	46.43	116.35	276.96	0.37	162.78	0.40	13.61	77.0	150.0	2.76	8.91	12.05	11.59	103.35
83	IL-144A	2	2	53.0	62.0	159.02	189.87	21.73	6.30	4.14	1.47	118.76	10.95	9.18	154.23	243.87	86.16	130.80	398.10	0.63	216.95	0.66	10.48	76.0	120.0	2.76	14.86	11.06	10.63	157.89
84	IL-3178	2	2	51.0	63.0	212.40	126.83	24.83	8.40	10.34	1.67	186.78	11.04	10.39	245.27	338.71	113.79	192.64	583.98	0.72	306.44	0.59	17.17	77.0	130.0	5.52	13.37	14.32	12.56	167.94
85	IL-160-A	2	3	51.0	63.0	157.54	119.99	25.87	8.40	6.21	1.67	114.45	11.82	10.09	254.10	277.75	107.30	147.70	531.85	0.91	255.00	0.73	13.07	74.0	120.0	1.38	5.94	12.05	7.73	45.93
86	HY-8-P-66	1	2	51.0	64.0	98.48	107.60	22.76	6.30	4.14	1.57	76.66	11.33	7.97	141.93	166.16	71.71	80.61	308.09	0.85	152.32	0.89	15.45	72.0	150.0	2.76	5.94	12.84	13.53	80.38
87	IL-2000-180	2	2	45.0	63.0	165.04	153.12	22.76	9.46	7.24	1.47	110.13	12.79	9.18	187.45	264.49	114.60	168.52	451.94	0.71	283.12	0.68	15.55	76.0	150.0	19.33	52.00	14.32	9.66	502.37
88	IL-2000-184	3	3	45.0	63.0	166.62	196.29	20.69	8.40	6.21	1.47	129.56	13.27	9.78	189.45	291.97	109.64	176.36	481.42	0.65	286.00	0.62	11.34	73.0	130.0	8.29	7.43	14.82	13.53	100.47
89	IL-2000-182	2	2	51.0	63.0	208.66	182.40	19.66	5.25	4.14	1.18	60.46	10.75	7.46	66.55	153.20	47.00	89.04	219.74	0.43	136.04	0.53	15.45	74.0	150.0	9.67	16.34	23.71	16.42	268.41
90	IL-2000-188	3	2	51.0	64.0	212.40	95.10	21.73	8.40	5.17	0.98	95.01	11.14	8.07	127.94	146.81	56.74	74.07	274.75	0.87	130.81	0.77	9.40	80.0	132.0	5.52	16.34	8.59	8.70	142.10

Highlights: : Higher values; : Lower values

Table A.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table A.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
91	IL-2000-187	2	3	41.0	54.0	157.88	190.52	18.62	7.35	4.14	1.08	61.54	13.37	10.59	97.04	154.84	45.09	89.84	251.88	0.63	134.94	0.50	13.50	69.0	134.0	2.76	14.86	12.35	10.63	157.89
92	IL-2000-178	2	2	54.0	67.0	283.62	93.71	17.59	4.20	4.14	1.27	48.59	13.76	10.99	115.64	220.94	64.46	119.04	336.58	0.52	183.50	0.54	17.71	70.0	150.0	2.76	16.34	12.84	11.59	189.47
93	IL-2000-179	2	2	55.0	68.0	192.75	123.95	20.69	7.35	9.31	1.37	87.45	10.95	8.98	124.37	175.84	70.12	98.78	300.21	0.71	168.91	0.71	13.50	72.0	134.0	4.14	28.23	10.27	8.70	245.45
94	IL-2000-189	2	5	42.0	55.0	159.81	150.34	14.49	5.25	4.14	1.18	48.91	13.76	9.68	126.16	183.87	56.26	106.71	310.03	0.69	162.97	0.53	11.99	69.0	134.0	5.52	35.66	11.26	7.73	275.59
95	IL-2000-183	2	5	56.0	99.0	171.85	151.73	20.69	7.35	4.14	1.27	76.66	12.40	7.46	140.14	196.74	59.03	91.89	336.88	0.71	150.92	0.64	12.21	82.0	150.0	4.14	13.37	11.56	10.63	142.10
96	EC-244236A	2	5	82.0	103.0	171.85	158.46	22.76	6.30	13.44	1.76	261.28	8.04	6.04	220.77	366.10	102.66	295.80	586.88	0.60	398.46	0.35	13.50	112.0	150.0	6.90	16.34	11.85	8.70	142.10
97	IL-178-4	2	5	45.0	88.0	121.68	155.23	18.00	6.61	4.35	1.70	184.56	12.98	9.48	223.40	326.33	120.86	126.28	549.72	0.68	247.13	0.96	13.79	72.0	141.0	11.56	35.10	14.45	13.63	478.30
98	IL-390	1	5	42.0	105.0	154.48	172.51	20.12	7.72	6.09	1.38	120.17	11.39	8.62	168.71	213.14	91.05	103.19	381.85	0.79	194.24	0.88	12.18	119.0	160.0	7.70	13.31	11.20	9.43	125.60
99	IL-131	2	2	51.0	65.0	121.38	153.16	27.53	9.92	8.71	1.81	198.05	12.56	10.56	271.45	371.60	116.40	166.27	643.05	0.73	282.67	0.70	12.75	78.0	141.0	6.42	16.95	11.20	9.43	159.85
100	IL-853	1	5	51.0	104.0	131.41	176.96	22.23	8.82	6.96	1.70	110.15	12.98	8.40	201.64	260.34	96.81	109.27	461.97	0.77	206.08	0.89	13.13	109.0	150.0	5.14	14.52	11.50	12.58	182.69
101	IL-1053	2	2	83.0	103.0	142.45	248.36	22.23	8.82	11.32	1.70	182.47	8.19	5.06	170.69	464.08	98.43	317.08	634.77	0.37	415.51	0.31	16.34	121.0	145.0	3.85	15.73	13.94	11.53	181.42
102	IL_246	2	4	83.0	103.0	167.53	165.89	24.35	5.51	7.83	1.59	202.50	7.55	5.08	155.10	369.79	108.32	249.41	524.89	0.42	357.72	0.43	16.62	114.0	150.0	3.85	14.52	12.52	9.43	137.02
103	IL-3171	2	5	83.0	103.0	179.56	187.31	26.47	8.82	12.19	2.01	276.00	9.04	7.11	329.63	709.30	210.91	610.44	1038.93	0.46	821.35	0.35	11.99	117.0	150.0	8.99	12.10	14.96	16.77	202.99
104	IL-380	2	5	83.0	103.0	142.45	144.88	18.00	5.51	6.96	0.96	206.95	7.34	5.17	122.17	294.29	82.92	278.56	416.46	0.42	361.48	0.30	11.43	116.0	134.0	7.70	10.89	14.55	15.72	171.27
105	IL-1057	1	2	51.0	101.0	187.59	192.17	23.29	7.72	3.48	1.49	296.80	12.98	9.80	319.67	433.86	86.47	318.20	753.53	0.74	404.67	0.27	15.02	115.0	150.0	11.56	26.63	17.30	19.92	530.31
106	IL-160-9	2	2	51.0	65.0	136.43	102.76	27.53	6.61	6.09	1.28	176.91	10.43	7.43	174.53	226.38	77.33	91.19	400.91	0.77	168.52	0.85	13.88	75.0	142.0	20.54	41.15	14.04	14.67	603.90
107	IL-622	2	5	82.0	103.0	156.49	125.22	15.88	3.31	1.74	0.96	83.45	10.85	7.22	120.19	252.75	69.27	207.67	372.94	0.48	276.93	0.33	14.45	116.0	147.0	14.12	25.42	11.40	13.63	346.35
108	IL-210	2	5	53.0	93.0	173.54	116.94	19.06	4.41	1.74	1.49	63.42	13.94	10.13	127.99	194.35	56.56	87.25	322.33	0.66	143.81	0.65	10.48	91.0	123.0	10.27	36.31	9.46	11.53	418.67
109	IL-3138-B	2	2	82.0	103.0	123.39	100.69	15.88	5.51	1.74	0.96	94.57	8.30	5.71	104.72	266.00	37.33	127.11	370.71	0.39	164.44	0.29	12.37	87.0	150.0	6.42	9.68	14.96	15.72	152.24
110	IL-892	2	2	51.0	85.0	180.27	210.07	25.41	6.61	3.48	1.28	107.93	16.60	12.60	230.73	422.54	92.14	311.11	653.26	0.55	403.25	0.30	16.62	117.0	140.0	2.57	4.84	11.91	12.58	60.90
111	IL-966-B	2	4	51.0	85.0	220.69	206.24	28.58	6.61	6.09	1.70	123.50	14.47	11.31	302.52	564.02	102.85	350.16	866.54	0.54	453.01	0.29	12.47	102.0	142.0	19.26	37.52	14.25	11.53	432.62
112	IL-1014-1	2	4	51.0	85.0	219.99	140.01	24.35	5.51	6.09	1.49	107.93	14.26	11.63	238.52	475.40	156.37	244.60	713.92	0.50	400.98	0.64	13.88	108.0	129.0	2.57	8.47	13.23	12.58	106.57
113	IL-416-4	2	5	51.0	85.0	280.58	126.98	31.76	7.72	6.09	1.49	205.84	12.24	9.69	263.77	452.76	139.78	186.09	716.53	0.58	325.87	0.75	13.79	103.0	135.0	3.85	9.68	11.20	11.53	111.64
114	IL-921	2	5	82.0	83.0	138.74	152.43	19.06	7.72	4.35	1.59	92.49	11.81	7.32	75.63	433.52	43.18	156.33	509.14	0.17	199.51	0.28	12.66	81.0	130.0	3.85	9.68	13.43	15.72	152.24
115	IL-380-A	3	5	50.0	106.0	145.46	189.07	16.94	7.72	3.48	1.49	94.57	13.19	9.69	174.53	303.69	86.48	118.20	478.22	0.57	204.68	0.73	12.37	84.0	142.0	5.14	10.89	14.55	14.67	159.85
116	IL-372	2	5	86.0	104.0	143.75	200.04	15.88	5.00	4.00	1.03	101.39	13.30	9.37	126.01	215.06	77.01	122.17	341.07	0.59	199.18	0.63	15.77	82.0	141.0	1.28	4.84	12.93	13.63	65.97
117	IL-419-1	2	5	53.0	98.0	198.92	197.66	33.00	5.51	3.48	1.70	116.83	14.68	10.66	263.77	439.51	125.20	254.55	703.29	0.60	379.75	0.49	15.02	81.0	140.0	15.41	35.10	16.28	12.58	441.50
118	IL-362	3	5	50.0	106.0	170.54	182.86	18.00	6.61	2.61	1.38	66.76	14.90	10.56	129.97	281.05	72.17	109.12	411.02	0.46	181.29	0.66	15.21	92.0	137.0	24.39	44.00	16.79	16.77	737.92
119	IL-812-1	2	5	48.0	90.0	163.51	192.17	19.06	6.61	3.48	1.38	71.21	15.75	10.13	238.52	282.97	112.29	126.78	521.50	0.84	239.07	0.89	14.36	90.0	136.0	14.12	23.00	17.61	14.67	337.47
120	IL-1050-3	2	5	86.0	104.0	224.00	222.49	31.76	7.72	6.96	1.59	278.16	7.13	5.71	186.16	479.13	125.21	370.09	665.30	0.39	495.31	0.34	11.05	91.0	138.0	1.28	8.47	12.52	13.63	115.45
121	IL-1177	2	5	60.0	75.0	250.84	221.79	27.48	8.14	19.00	2.50	371.90	14.02	9.30	504.47	601.00	256.92	452.29	1105.47	0.84	709.21	0.57	12.57	87.0	131.0	0.98	5.05	11.09	9.88	49.89
122	IL-867	3	2	42.0	71.0	121.14	133.67	19.63	6.10	1.77	1.59	83.25	14.56	10.67	192.44	329.15	138.76	216.24	521.59	0.58	355.01	0.64	14.73	102.0	128.0	12.77	41.42	13.12	8.89	368.18
123	IL-161-1	1	1	42.0	76.0	119.12	102.54	18.65	6.10	5.32	1.09	77.04	14.87	8.71	141.12	168.47	96.49	72.23	309.59	0.84	168.72	1.34	8.45	99.0	134.0	6.88	22.23	11.60	10.86	241.46
124	IL_153-1	2	4	60.0	75.0	168.68	174.31	20.61	6.10	15.00	1.49	160.87	13.60	10.96	292.89	425.23	155.55	226.82	718.13	0.69	382.37	0.69	18.13	86.0	123.0	0.98	21.22	9.97	3.95	83.81
125	IL-812	2	2	86.0	104.0	138.61	180.96	21.60	10.17	17.74	0.91	217.22	9.88	6.16	198.85	271.41	100.14	182.05	470.26	0.73	282.19	0.55	12.67	112.0	129.0	2.95	4.04	10.38	7.90	31.93
126	IL-200	2	4	60.0	75.0	111.87	121.81	23.56	9.15	19.00	1.70	216.39	12.32	7.73	235.16	509.23	134.07	237.62	744.39	0.46	371.69	0.56	9.58	87.0	132.0	5.90	19.20	10.07	8.89	170.62
127	IL-893	2	4	42.0	72.0	160.46	163.59	17.67	6.10	1.77	1.38	78.17	14.02	9.00	181.66	212.96	117.03	134.40	394.63	0.85	251.43	0.87	17.00	95.0	134.0	5.90	20.21	13.23	12.84	259.42
128	IL-156	1	4	53.0	67.0	113.62	142.98	18.65	9.15	7.10	1.38	113.29	12.54	6.95	186.02	240.04	74.40	107.19	426.06	0.77	181.59	0.69	21.01	81.0	139.0	23.58	55.57	12.31	11.85	658.53
129	IL-1182	2	4	42.0	77.0	142.98	110.13	13.74	4.07	1.77	0.74	53.25	11.05	7.24	83.39	104.57	35.31	64.60	187.96	0.80	99.91	0.55	16.17	90.0	125.0	13.76	41.42	12.11	9.88	409.08
130	IL-4216	3	2	42.0	75.0	137.48	151.53	19.63	9.15	10.64	1.59	122.35	10.73	7.93	235.16	284.65	85.63	105.23	519.81	0.83	190.86	0.81	21.01	89.0	137.0	6.88	21.22	13.12	11.85	251.44
131	IL-380B	3	4	45.0	81.0	156.97	155.99	17.67	7.12	5.32	1.81	128.02	13.71	9.39	198.85	300.10	161.45	202.08	498.96	0.66	363.52	0.80	17.61	104.0	138.0	10.81	31.32	15.87	11.85	371.17
132	IL-1177-A	2	4	42.0	82.0	199.88	164.91	19.63	4.07	3.55	1.27	45.32	14.02	10.27	158.04	205.18	53.26	78.84	363.22	0.77	132.10	0.68	7.00	105.0	142.0	8.84	28.29	14.96	12.84	363.19
133	IL-380-C	2	4	42.0	91.0	135.21	175.36	16.69	5.09	7.10	1.27	41.92	12.86	9.00	138.94	269.20	43.43	119.37	408.14	0.52	162.80	0.36	11.23	103.0	140.0	2.95	9.09	13.12	10.86	98.78
134	IL-578-A	2	4	41.0	75.0	145.08	116.49	13.74	4.07	3.55	1.17	54.38	14.13	8.22	70.56	137.45	46.97	51.11	208.01	0.51	98.08	0.92	6.59	90.0	146.0	2.95	9.09	9.97	7.90	71.84
135	IL-370	2	2	86.0	104.0	140.97	193.97	20.61	8.14	15.96	0.96	145.01	9.56	6.75	143.30	354.36	62.09	262.23	497.66	0.40	324.32	0.24	11.85	118.0	140.0	2.95	14.14	14.96	12.84	181.59

Highlights: : Higher values; : Lower values

Table A.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-100 SW: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table A.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
136	IL-1170-A	3	2	63.0	93.0	182.05	191.78	19.63	6.10	3.55	1.49	73.64	14.02	8.90	254.41	302.08	100.55	125.27	556.48	0.84	225.82	0.80	14.73	103.0	125.0	3.93	12.12	11.09	8.89	107.76
137	IL-1072-1-5	3	4	42.0	102.0	142.72	177.26	18.65	6.10	9.00	1.81	105.36	13.60	9.10	292.89	404.67	109.99	212.84	697.56	0.72	322.83	0.52	13.80	115.0	142.0	3.93	11.11	14.96	11.85	131.71
138	IL-419-2	2	2	57.0	67.0	175.67	173.74	21.60	7.12	12.42	1.49	102.00	14.45	7.63	201.04	420.24	88.28	186.96	621.27	0.48	275.24	0.47	15.66	81.0	137.0	7.86	21.22	16.08	14.81	314.30
139	IL-893-1	1	5	42.0	71.0	134.33	155.99	16.69	5.09	1.77	1.70	158.00	15.09	10.67	245.94	362.15	86.15	123.27	608.08	0.68	209.42	0.70	17.61	85.0	136.0	10.81	29.30	15.97	12.84	376.16
140	IL-14177-A	3	5	45.0	74.0	164.92	97.79	13.74	4.07	3.55	1.38	98.00	13.71	8.51	186.02	232.37	73.88	85.96	418.39	0.80	159.84	0.86	15.66	84.0	125.0	13.76	41.42	16.79	13.83	572.72
141	IL-1086-2	2	2	48.0	76.0	179.78	84.50	18.65	5.09	3.55	1.59	84.58	12.32	8.22	160.37	245.96	35.88	55.79	406.33	0.65	91.66	0.64	12.67	90.0	132.0	4.91	18.18	17.40	14.81	269.40
142	IL-155	3	5	57.0	67.0	142.72	112.03	25.52	8.14	21.29	1.27	243.58	10.41	8.02	404.12	520.85	150.94	385.72	924.98	0.78	536.67	0.39	8.96	80.0	121.0	7.86	26.27	9.08	7.90	207.54
143	IL-216-1	2	5	48.0	78.0	170.69	155.42	18.65	5.09	3.55	1.38	100.00	14.45	10.67	218.10	292.43	64.08	102.78	510.53	0.75	166.86	0.62	11.02	92.0	130.0	11.79	41.42	13.84	12.84	531.81
144	IL-887	2	2	48.0	79.0	164.92	148.39	20.61	7.12	5.32	1.38	83.84	15.30	9.10	198.85	271.06	80.84	115.25	469.91	0.73	196.09	0.70	15.14	92.0	133.0	5.90	30.31	14.14	13.83	419.06
145	IL-160-11	2	2	42.0	78.0	141.41	123.70	24.71	8.61	3.47	1.40	98.00	14.86	10.01	221.02	270.90	132.95	155.09	491.92	0.82	288.04	0.86	15.71	111.0	126.0	14.81	43.00	17.79	16.45	707.18
146	IL-1721	3	2	45.0	105.0	182.23	137.00	22.56	6.46	2.32	1.40	59.92	13.06	11.54	185.71	246.68	91.07	107.39	432.38	0.75	198.46	0.85	14.10	118.0	135.0	15.80	31.38	17.36	16.45	516.08
147	IL-3152-1	1	2	45.0	58.0	169.12	153.70	24.71	7.54	6.95	1.30	142.80	12.36	8.07	211.98	291.60	109.58	104.19	503.58	0.73	213.77	1.05	8.03	72.0	137.0	6.91	20.92	11.07	11.75	245.75
148	IL-3155	2	4	45.0	58.0	162.30	128.30	23.63	9.69	8.10	1.30	106.85	11.95	7.87	168.16	258.79	74.98	104.33	426.94	0.65	179.32	0.72	7.23	71.0	131.0	7.90	18.83	11.94	14.10	265.41
149	IL-18720-A	1	2	42.0	91.0	137.15	114.00	23.63	7.54	3.47	1.40	89.87	15.79	10.11	224.18	301.95	90.46	119.42	526.13	0.74	209.88	0.76	14.73	115.0	133.0	0.99	6.28	13.45	17.62	110.59
150	IL-3168-B	2	2	86.0	104.0	178.71	194.29	22.56	5.38	9.26	1.61	130.82	9.25	7.87	126.12	296.78	66.25	247.86	422.89	0.42	314.11	0.27	11.51	117.0	135.0	1.97	8.37	13.35	15.27	127.79
151	IL-632	2	2	57.0	67.0	160.91	138.30	22.56	4.00	2.00	1.20	74.89	15.48	11.24	150.61	137.99	82.65	107.48	288.59	1.09	190.13	0.77	12.14	81.0	136.0	3.95	16.74	12.04	14.10	235.92
152	IL-1156-1	2	5	53.0	58.0	173.38	191.29	19.34	4.31	4.63	1.40	75.89	13.30	10.01	151.05	229.49	76.81	108.97	380.54	0.66	185.77	0.70	13.92	71.0	134.0	9.87	35.56	18.34	19.97	710.22
153	IL-1177-B	2	5	45.0	55.0	143.12	160.70	24.71	6.46	4.63	1.61	115.84	13.09	9.71	229.43	355.37	97.36	162.59	584.80	0.65	259.95	0.60	10.09	66.0	132.0	19.75	42.00	15.19	17.62	740.07
154	EC-24102-1	2	5	54.0	58.0	199.28	134.30	21.48	5.38	2.32	1.40	58.92	14.03	10.73	204.94	298.43	88.86	135.51	503.38	0.69	224.37	0.66	12.59	72.0	134.0	23.70	43.00	16.60	17.62	757.69
155	RAJL-2	1	2	57.0	67.0	190.75	181.00	23.63	8.61	16.21	1.30	124.00	14.44	8.58	194.18	284.67	84.72	153.24	478.84	0.68	237.96	0.55	7.50	81.0	130.0	1.97	14.64	9.77	11.75	172.03
156	IL-1063	3	2	57.0	67.0	202.79	135.00	24.71	6.46	6.95	1.10	107.85	12.36	9.40	140.86	225.97	73.52	116.59	366.84	0.62	190.11	0.63	9.28	81.0	133.0	2.96	11.51	11.39	10.57	121.65
157	IL-182	3	5	52.0	69.0	152.39	171.30	20.41	5.38	3.47	1.40	91.00	12.36	9.71	134.84	207.03	54.09	95.38	341.87	0.65	149.48	0.57	11.69	73.0	143.0	2.96	10.46	15.19	15.27	159.74
158	RAJL-16	1	2	54.0	69.0	172.63	181.70	15.04	7.54	10.42	1.30	122.83	15.27	8.28	239.94	298.43	87.86	146.82	538.37	0.80	234.69	0.60	7.23	73.0	130.0	2.96	12.55	14.32	14.10	176.94
159	IL-200-186	3	5	54.0	69.0	203.54	111.00	19.34	4.31	2.32	1.10	72.00	13.61	10.32	119.08	194.92	52.49	75.15	313.99	0.61	127.64	0.70	16.24	72.0	134.0	3.95	13.60	14.32	12.92	175.71
160	IL-14	1	4	54.0	69.0	278.00	128.00	24.71	4.31	8.10	1.00	77.89	13.92	9.81	199.69	295.02	54.09	131.82	494.70	0.68	185.91	0.41	16.33	70.0	129.0	2.96	6.28	15.19	17.62	110.59
161	IL-3192	2	2	52.0	89.0	182.55	163.00	23.63	7.54	4.63	1.40	102.86	15.90	11.54	255.70	372.65	91.75	141.93	628.36	0.69	233.68	0.65	9.64	101.0	134.0	2.96	11.51	9.77	8.22	94.61
162	IL-3177	2	2	57.0	89.0	231.57	143.00	26.86	7.54	5.79	1.40	141.80	12.68	9.91	196.22	310.54	94.24	162.49	506.76	0.63	256.73	0.58	8.84	100.0	130.0	5.92	14.64	13.02	10.57	154.82
163	IL-3157	2	2	54.0	69.0	205.67	160.00	24.71	6.46	6.95	1.10	95.88	11.53	9.30	207.04	353.71	115.82	140.19	560.75	0.59	256.01	0.83	9.28	72.0	132.0	9.87	32.00	15.19	18.80	601.45
164	IL-160-C	3	4	54.0	69.0	171.25	171.70	25.78	6.46	5.79	1.20	123.83	13.40	7.56	178.67	229.49	55.43	77.11	408.16	0.78	132.54	0.72	9.55	73.0	124.0	2.96	11.51	8.68	7.05	81.10
165	IL_892	2	5	54.0	59.0	275.26	269.69	29.00	7.54	6.95	2.00	106.85	12.99	10.32	320.55	520.99	189.48	369.56	841.54	0.62	559.03	0.51	13.12	72.0	134.0	0.99	2.09	11.94	10.57	22.12
166	IL-449	2	5	53.0	69.0	167.31	192.99	23.63	8.61	9.26	1.90	127.82	12.88	9.81	317.08	484.76	166.86	279.25	801.84	0.65	446.12	0.60	15.98	72.0	132.0	8.89	19.87	14.54	14.10	280.16
167	IL-1471	2	2	42.0	79.0	253.94	209.99	29.00	6.46	5.79	1.80	125.82	13.40	9.81	299.53	502.05	128.61	399.57	801.58	0.60	528.18	0.32	12.67	72.0	134.0	7.90	32.43	15.73	16.45	533.28
168	IL-4170	2	4	42.0	79.0	198.21	175.00	33.00	5.38	3.47	1.20	87.88	10.39	7.25	146.50	222.56	55.09	108.97	371.06	0.67	164.06	0.51	9.73	106.0	134.0	2.96	13.60	14.11	14.10	191.69
169	BL-1	2	2	48.0	68.3	167.79	184.37	21.86	6.00	4.00	1.33	84.29	12.41	9.44	204.03	318.33	94.94	110.86	522.36	0.64	205.80	0.86	12.77	83.6	133.0	5.43	17.86	12.31	13.14	234.69
170	BL-2	2	2	63.4	80.1	155.81	139.49	22.43	5.71	6.86	1.36	126.43	11.01	8.70	138.76	273.54	77.18	152.10	412.30	0.51	229.28	0.51	14.33	93.0	137.3	7.43	21.86	12.04	12.14	265.41
171	UPC-5286	2	3	73.7	88.0	177.00	158.81	20.00	6.14	6.14	1.66	131.29	12.14	8.64	169.61	294.04	94.38	200.08	463.66	0.58	294.47	0.47	13.81	94.9	134.3	7.14	16.43	13.73	11.71	192.45
172	IGFRI-95-1	2	1	50.7	66.6	201.43	128.04	19.43	5.14	1.86	1.29	68.29	13.50	9.59	142.56	191.40	83.21	116.28	333.96	0.74	199.49	0.72	10.07	79.3	115.0	13.71	32.71	11.13	11.29	369.20

Highlights: : Higher values; : Lower values

Trait Names – 1-EPV: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Appendix B

Table B.1 Morphological traits recorded for evaluated germplasm lines during the year 2005-06

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➤	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	Hy10-36-4	1	1	43.0	64.0	191.25	167.37	21.82	3.79	1.69	0.94	49.62	13.63	2.72	132.75	224.80	62.69	77.08	357.55	0.59	139.77	0.81	17.48	78.0	132.0	10.39	26.24	18.32	18.37	482.02
2	EC-48720	2	2	44.0	74.0	186.18	183.34	20.73	3.79	5.08	0.68	35.11	7.16	10.08	129.46	274.92	42.30	61.07	404.38	0.47	103.37	0.69	15.63	92.0	142.0	4.16	5.47	13.74	16.07	87.87
3	IVM-1	2	1	68.0	88.0	157.30	116.59	27.27	5.05	3.38	1.02	57.93	14.54	8.37	165.99	201.64	73.41	114.67	367.64	0.82	188.09	0.64	17.48	108.0	140.0	6.23	5.47	11.50	14.92	81.59
4	EC-244310	2	4	43.0	64.0	116.35	153.08	21.82	2.53	13.00	0.68	32.25	7.38	4.54	58.40	208.94	29.77	72.60	267.34	0.28	102.37	0.41	8.59	99.0	112.0	5.20	7.65	12.21	12.63	96.66
5	EC-240564	2	5	43.0	64.0	149.09	138.63	17.45	2.53	13.00	0.57	44.00	4.88	2.02	81.69	200.80	34.70	46.09	282.49	0.41	80.78	0.75	16.80	78.0	131.0	3.12	14.21	15.17	16.07	228.46
6	EC-244979	2	5	44.0	84.0	190.87	152.73	16.36	3.79	3.38	0.91	32.25	7.72	2.82	90.55	202.59	32.94	91.54	293.15	0.45	124.48	0.36	14.75	80.0	105.0	4.16	15.31	16.79	14.92	228.46
7	EC-240887	3	5	43.0	64.0	140.12	145.25	15.27	5.05	3.38	0.91	28.53	12.61	4.03	68.90	202.91	38.81	96.34	271.82	0.34	135.15	0.40	15.63	64.0	143.0	9.35	36.08	16.29	16.07	579.93
8	HY10P527	2	2	48.0	68.0	119.18	198.93	20.40	3.79	1.69	1.13	16.13	7.95	1.51	63.42	128.68	18.53	78.86	182.10	0.42	97.39	0.24	9.47	78.0	143.0	5.20	6.56	11.09	9.18	60.25
9	HY6P52-3	2	5	48.0	68.0	162.20	110.05	23.67	8.84	6.77	1.24	86.84	16.47	6.35	198.53	189.91	113.73	158.62	388.43	1.05	272.35	0.72	12.60	79.0	134.0	4.16	27.33	13.64	19.52	533.49
10	EC-240884	3	5	43.0	64.0	139.37	65.34	19.64	3.79	1.69	0.68	37.00	11.70	3.63	101.10	201.01	60.84	113.05	302.11	0.50	173.89	0.54	16.60	80.0	120.0	6.23	14.21	18.32	16.07	228.46
11	EC-244236	2	5	47.0	68.0	124.28	143.30	24.00	7.58	6.77	1.36	33.87	16.72	4.44	127.01	212.11	45.15	152.03	339.12	0.60	197.18	0.30	18.26	119.0	147.0	6.23	10.93	13.33	17.22	188.29
12	NP-3-14-A	3	5	43.0	64.0	109.74	126.71	13.42	3.79	1.69	0.68	11.16	4.32	1.11	82.32	117.05	21.13	48.04	169.37	0.45	69.17	0.44	15.24	75.0	131.0	4.16	12.03	12.11	12.63	151.89
13	HY6P52-10	2	5	41.0	64.0	144.66	156.52	17.13	5.05	1.69	0.71	17.37	5.34	1.51	66.67	136.93	22.03	56.78	203.60	0.49	78.82	0.39	16.02	71.0	131.0	9.35	28.43	15.27	16.07	456.92
14	HY6P52-9	3	5	68.0	88.0	147.49	175.74	26.18	4.17	3.38	1.13	59.55	14.76	5.85	96.29	171.93	59.53	133.65	268.22	0.56	193.18	0.45	17.19	96.0	145.0	3.12	5.47	14.25	14.92	81.59
15	HY-10P583	3	5	48.0	68.0	134.94	131.05	19.64	7.58	6.77	0.91	55.45	11.70	5.55	115.53	147.82	43.45	117.19	263.35	0.78	160.64	0.37	14.46	79.0	138.0	4.16	29.52	15.67	19.52	576.17
16	EC120001	3	5	44.0	65.0	241.29	71.08	29.45	7.58	5.08	0.91	58.31	14.20	7.06	106.50	148.25	32.17	73.87	254.75	0.72	106.04	0.44	17.87	80.0	155.0	5.20	12.03	17.00	21.00	252.57
17	EC241023	3	5	68.0	88.0	111.07	114.64	19.64	6.31	5.08	1.13	44.66	13.97	4.23	89.29	186.52	31.62	102.90	275.81	0.48	134.51	0.31	16.02	98.0	137.0	5.20	7.65	16.29	19.52	149.38
18	EC244223-1	2	5	48.0	65.0	109.18	152.13	19.64	7.58	5.08	1.05	79.39	12.71	11.29	104.60	122.23	48.30	70.18	226.83	0.86	118.48	0.69	11.19	79.0	151.0	2.08	17.49	11.91	14.92	261.10
19	NP-3-7	2	2	61.0	65.0	231.19	149.29	28.36	5.05	1.69	1.02	40.07	13.29	5.75	110.30	203.23	17.29	46.19	313.53	0.54	63.48	0.37	20.08	79.0	122.0	13.51	39.36	21.58	18.37	723.03
20	EC-240714	2	2	44.0	63.0	171.74	91.71	25.09	5.05	1.69	1.13	38.46	12.83	5.04	90.72	183.24	35.62	94.04	273.96	0.50	129.66	0.38	15.04	72.0	112.0	4.16	21.87	18.73	16.07	351.47
21	EC-244243	2	5	68.0	88.0	120.12	82.54	19.64	5.05	5.08	1.02	27.29	8.52	3.02	69.45	241.72	30.75	93.73	311.17	0.29	124.48	0.33	17.66	115.0	140.0	17.66	33.90	15.06	13.78	466.96
22	EC-240840	2	5	68.0	88.0	132.11	105.47	22.91	6.31	3.38	1.24	35.98	11.93	4.34	86.67	145.07	26.19	93.05	231.74	0.60	119.23	0.28	17.19	119.0	158.0	11.43	24.05	16.29	17.22	414.24
23	NP-3-10	2	2	44.0	65.0	100.02	120.37	22.91	7.58	3.38	1.13	73.00	13.74	7.06	99.16	133.97	43.88	84.27	233.13	0.74	128.14	0.52	19.53	61.0	151.0	5.20	9.84	11.20	19.52	192.06
24	EC-244249	2	5	60.0	65.0	146.55	124.96	16.36	6.31	1.69	0.83	28.04	9.65	3.73	65.06	104.47	28.63	44.40	169.53	0.62	73.04	0.64	17.19	79.0	148.0	5.20	29.52	17.30	18.37	542.28
25	HY-5P-6S-215	2	5	41.0	51.0	105.04	63.42	20.22	4.35	2.78	1.08	17.93	14.14	3.28	92.72	150.11	30.64	81.42	242.83	0.62	112.06	0.38	15.80	68.0	133.0	13.11	22.76	15.30	13.41	305.09
26	EC-244217	2	2	71.0	88.0	175.54	113.21	20.22	5.00	5.00	0.86	17.10	14.47	6.27	96.28	218.71	16.08	69.62	314.99	0.44	85.69	0.23	19.08	95.0	133.0	3.03	9.63	11.48	8.62	82.98
27	IVM	2	1	71.0	88.0	96.29	51.09	20.22	5.43	1.85	1.08	27.26	10.12	4.03	74.02	162.53	22.32	54.91	236.55	0.46	77.23	0.41	18.88	126.0	150.0	6.05	8.75	15.11	17.24	150.87
28	EC-240998	2	2	68.0	89.0	106.79	76.90	20.93	4.35	1.85	1.30	11.57	10.34	1.59	37.55	126.90	14.96	53.68	164.45	0.30	68.64	0.28	17.07	95.0	161.0	7.06	12.25	12.43	12.45	152.55
29	EC-240650	2	2	81.0	65.0	147.67	141.40	27.60	5.43	1.85	0.97	48.50	16.32	8.14	88.06	162.53	20.70	58.62	250.59	0.54	79.32	0.35	17.05	71.0	133.0	6.05	12.25	12.43	12.45	152.55
30	RA-2	3	4	81.0	65.0	107.05	49.06	15.17	3.26	0.93	0.54	19.83	4.13	2.53	32.55	191.27	18.46	91.33	223.82	0.17	109.79	0.20	11.62	120.0	135.0	6.05	24.51	11.38	12.45	305.09
31	EC-240999	3	5	58.0	67.0	122.55	157.06	23.25	7.60	5.55	1.51	68.58	2.50	1.12	45.94	201.18	31.78	134.75	247.12	0.23	166.53	0.24	21.11	120.0	135.0	4.03	7.00	16.36	13.41	93.87
32	UPC-870	2	5	61.0	65.0	188.41	185.18	14.88	5.43	1.85	1.19	27.84	6.85	3.46	56.11	154.12	29.65	53.72	210.23	0.36	83.37	0.55	14.66	95.0	135.0	6.05	8.75	17.22	15.32	134.11
33	HY-10-P-10-2-4	3	5	60.0	89.0	215.28	195.13	17.19	6.52	2.78	1.19	45.19	11.97	5.90	60.35	197.88	37.92	90.63	258.22	0.30	128.55	0.42	22.74	95.0	113.0	12.10	19.26	16.16	13.41	258.15
34	RAJL-4	2	5	65.0	85.0	128.41	97.78	15.17	5.43	1.85	0.76	53.00	8.81	2.06	129.00	200.58	77.09	94.37	329.58	0.64	171.47	0.82	10.43	76.0	137.0	10.08	20.13	11.86	10.53	212.06
35	NP-3-8	2	5	65.0	85.0	173.31	132.13	21.23	5.43	7.40	1.08	23.13	13.27	3.74	40.51	159.42	20.73	101.55	199.94	0.25	122.27	0.20	16.28	95.0	123.0	5.04	5.25	11.76	11.49	60.35
36	EC-240800	3	5	41.0	51.0	107.67	97.52	16.48	3.26	4.00	0.86	48.00	8.16	3.93	89.84	183.06	42.51	86.61	272.90	0.49	129.12	0.49	17.47	80.0	138.0	13.11	27.13	15.78	13.41	363.76
37	EC-240740	3	5	43.0	52.0	95.15	71.09	17.19	3.26	2.00	0.86	46.00	6.53	3.09	75.60	123.97	22.70	66.94	199.58	0.61	89.64	0.34	16.32	78.0	128.0	6.05	19.26	14.35	12.45	239.72
38	EC-244217-1	2	5	39.0	50.0	112.04	132.86	18.50	2.17	0.93	0.76	33.00	5.77	2.81	52.62	126.88	30.83	34.28	179.49	0.41	65.11	0.90	13.37	76.0	128.0	12.10	28.88	15.30	16.28	470.21
39	NP-3-14-B	3	5	71.0	89.0	116.42	119.53	22.24	4.35	3.70	1.08	36.11	13.27	5.62	91.28	165.93	48.99	82.79	257.22	0.55	131.78	0.59	17.93	78.0	135.0	2.02	19.26	15.59	13.41	258.15
40	EC-240842	2	5	71.0	89.0	136.92	93.52	17.19	2.17	2.78	0.86	13.22	4.90	1.68	28.22	90.13	21.20	33.47	118.35	0.31	54.67	0.63	20.57	126.0	142.0	3.03	6.13	16.36	15.32	93.87
41	Local-3	2	5	40.0	51.0	108.54	84.56	14.15	5.43	1.85	1.19	19.83	14.14	4.68	98.91	177.05	22.71	61.71	275.96	0.56	84.42	0.37	19.66	80.0	140.0	13.11	23.63	10.43	7.66	181.04
42	Local-2	2	5	62.0	75.0	109.68	89.85	14.15	5.11	2.78	0.54	25.36	5.98	2.62	39.56	89.71	18.00	48.46	129.27	0.44	66.46	0.37	22.42	91.0	130.0	10.08	14.00	21.90	22.00	308.08
43	Local-1	2	5	47.0	65.0	181.19	116.54	21.53	5.11	2.78	0.97	36.60	10.88	5.15	64.33	98.74	39.26	109.66	163.07	0.65	148.91	0.36	18.21	78.0	126.0	9.08	10.50	25.25	21.00	220.56
44	NP-3-7-1	3	5	41.0	49.0	133.31	111.61	24.57	3.26	0.93	0.86	21.48	9.25	2.81	81.71	193.17	25.28	72.88	274.88	0.42	98.16	0.35	22.88	80.0	124.0	8.07	18.38	16.55	13.41	246.42
45	HY-5p-32-2b	2	5	44.0	65.0	123.16	109.84	18.20	3.26	2.78	1.08	25.36	8.16	4.68	82.38	164.93	22.22	58.57	247.31	0.50	80.79	0.38	15.96	79.0	133.0	5.04	14.00	16.64	17.24	241.39

Highlights: : Higher values; : Lower values

Table B.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table B.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➤	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
46	EC-24077	2	5	71.0	89.0	125.78	83.42	21.94	4.35	2.78	1.40	51.80	13.82	5.34	94.07	162.83	39.92	78.27	256.90	0.58	118.19	0.51	18.60	98.0	125.0	4.03	10.50	16.16	15.32	160.93
47	NP-652-Y	3	5	47.0	69.0	106.79	82.18	16.88	5.11	2.78	1.30	25.61	10.34	4.40	88.40	183.16	25.03	65.34	271.56	0.48	90.38	0.38	16.49	81.0	134.0	10.08	14.00	13.29	11.49	160.93
48	IL-99-69	2	5	61.0	69.0	209.68	201.40	19.51	4.35	2.78	1.08	22.89	8.49	3.00	64.08	155.12	37.58	54.53	219.20	0.41	92.11	0.69	12.97	80.0	151.0	17.14	37.64	14.06	13.41	504.58
49	EC-241037	1	5	58.0	66.0	126.18	128.29	21.58	4.80	2.48	0.75	40.15	13.59	6.08	130.89	217.62	36.20	50.21	348.50	0.60	86.41	0.72	14.00	123.0	132.0	5.15	4.60	17.40	15.08	69.43
50	EC240698	2	5	53.0	65.0	161.49	87.47	18.17	2.40	2.48	0.75	40.15	5.46	2.79	89.45	129.51	18.21	33.50	218.97	0.69	51.71	0.54	20.03	80.0	145.0	5.15	11.05	12.86	9.05	99.98
51	HY-6P-05-28	2	5	51.0	66.0	183.43	156.06	25.32	4.80	3.71	0.96	41.49	7.88	2.92	96.27	142.51	30.20	51.21	238.78	0.68	81.41	0.59	14.95	86.0	132.0	5.15	10.13	15.47	15.08	152.75
52	EC-240782	3	5	45.0	65.0	120.28	95.51	15.44	4.80	2.48	0.85	49.52	7.04	3.55	92.87	115.89	32.39	35.85	208.75	0.80	68.24	0.90	20.61	61.0	142.0	6.18	13.81	15.37	16.09	222.18
53	IL-181	2	5	72.0	106.0	154.80	92.02	22.71	7.21	2.48	1.28	60.23	14.19	8.62	118.17	129.30	44.93	65.32	247.48	0.91	110.25	0.69	25.73	74.0	116.0	4.12	12.89	13.44	9.05	116.64
54	IL-792	2	1	51.0	66.0	135.09	92.40	14.00	3.00	3.71	0.85	104.39	11.28	8.49	96.96	85.92	58.64	53.42	182.88	1.13	112.06	1.10	10.05	80.0	124.0	13.40	19.33	8.99	8.04	155.53
55	IL-179	3	1	54.0	66.0	159.26	143.36	14.00	4.80	3.71	0.75	40.15	7.04	4.44	52.02	103.46	25.35	30.73	155.48	0.50	56.08	0.82	10.80	77.0	132.0	19.58	37.75	12.57	12.07	455.47
56	IL-90	3	1	53.0	66.0	208.26	163.51	31.00	8.41	2.48	1.28	78.96	10.13	8.24	115.70	138.39	36.58	75.97	254.09	0.84	112.55	0.48	10.43	77.0	135.0	29.89	55.24	11.51	12.07	666.54
57	IL-178-8	2	3	51.0	66.0	187.10	122.26	29.07	7.21	6.19	0.75	70.93	14.19	8.49	103.81	133.11	27.95	54.20	236.92	0.78	82.15	0.52	23.47	78.0	141.0	6.18	5.52	12.57	13.07	72.21
58	EC-240809	2	3	54.0	66.0	164.05	167.69	23.85	3.60	2.48	0.96	26.77	7.28	4.06	85.81	120.32	25.55	32.21	206.13	0.71	57.77	0.79	16.17	82.0	137.0	21.64	40.51	22.14	18.10	733.19
59	IL-55-1	3	4	61.0	66.0	125.63	175.41	22.71	12.01	9.90	1.39	144.54	10.04	9.51	73.21	96.66	65.50	62.27	169.87	0.76	127.76	1.05	14.69	79.0	140.0	10.31	11.97	20.11	19.11	228.66
60	IL-177	2	4	51.0	65.0	143.67	153.94	20.44	4.80	2.48	0.75	24.09	5.82	3.17	44.02	103.56	30.56	86.37	147.58	0.43	116.93	0.35	21.50	78.0	142.0	5.15	19.33	16.44	17.09	330.49
61	RAJ-2	3	1	61.0	65.0	170.73	86.30	24.98	3.60	3.71	0.85	23.00	7.88	2.53	34.72	105.67	20.85	54.04	140.39	0.33	74.89	0.39	9.98	82.0	131.0	6.18	18.41	9.57	9.05	166.63
62	IL-99-40	3	1	51.0	88.0	166.28	107.88	22.71	4.80	2.48	0.96	26.00	11.16	6.08	35.19	94.62	27.68	74.47	129.81	0.37	102.16	0.37	10.47	82.0	126.0	11.34	27.62	14.50	14.08	388.81
63	IL-99-38	3	1	50.0	62.0	145.90	156.06	14.76	1.20	1.24	0.53	20.08	9.79	5.15	35.31	63.38	24.50	40.59	98.69	0.56	65.09	0.60	10.60	79.0	125.0	9.27	17.49	12.57	11.06	193.48
64	IL-99-34	2	1	52.0	62.0	149.90	168.17	27.25	4.80	3.71	1.18	95.02	11.35	8.24	97.08	153.38	53.16	70.52	250.46	0.63	123.69	0.75	10.43	75.0	121.0	9.27	17.49	12.57	10.06	175.89
65	IL-99-98-1	3	4	68.0	89.0	122.06	112.72	15.10	3.60	2.48	0.64	18.74	3.88	2.28	54.38	81.34	25.35	35.25	135.72	0.67	60.60	0.72	15.20	81.0	126.0	6.18	11.97	12.57	9.05	108.31
66	IL-99-98	3	4	53.0	89.0	123.96	137.02	13.63	2.40	1.24	0.75	14.72	2.67	8.37	27.90	103.21	8.84	58.86	131.11	0.27	67.70	0.16	12.42	80.0	121.0	7.21	10.13	8.90	13.07	132.38
67	IL-99-73	3	4	54.0	62.0	154.80	62.72	29.52	3.60	2.48	0.64	32.12	7.52	4.18	64.50	82.72	37.82	40.12	147.22	0.78	77.93	0.94	13.36	78.0	115.0	8.24	22.10	13.05	9.05	199.96
68	IL-99-2	3	4	53.0	68.0	174.07	95.82	23.85	6.00	3.71	1.28	54.87	11.52	6.59	72.27	108.17	45.44	39.88	180.44	0.67	85.32	1.14	12.51	77.0	122.0	9.27	26.70	12.38	10.06	268.47
69	IL-99-72	3	4	53.0	62.0	237.32	149.29	17.03	3.60	1.24	0.96	30.78	8.73	4.69	61.44	106.06	16.02	56.33	167.50	0.58	72.35	0.28	10.58	78.0	114.0	8.24	51.56	13.54	13.07	673.95
70	IL-99-65	2	4	41.0	69.0	193.78	94.77	21.12	4.80	2.48	0.75	45.50	10.55	5.07	97.43	170.07	34.75	57.05	267.50	0.57	91.80	0.61	11.25	78.0	112.0	5.15	28.54	9.98	10.06	286.98
71	IL-01-88	2	5	46.0	60.0	217.51	70.44	19.64	4.80	3.71	0.75	36.14	7.88	4.18	83.80	139.13	33.04	46.89	222.93	0.60	79.93	0.70	17.61	77.0	137.0	4.12	11.05	12.18	15.08	166.63
72	IL-99-171	3	5	44.0	62.0	188.55	127.55	19.30	3.60	2.48	0.85	37.47	6.67	4.18	82.37	60.43	24.94	49.52	142.80	1.36	74.46	0.50	14.95	80.0	118.0	13.40	30.38	15.37	17.09	519.35
73	IL-3117	1	2	43.0	67.0	199.06	45.57	32.52	2.01	1.11	0.88	35.10	7.19	3.40	88.54	125.62	28.82	37.72	214.16	0.70	66.54	0.76	19.79	79.0	132.0	19.12	44.76	15.80	16.06	718.77
74	IL-15-1	2	2	64.0	90.0	109.54	145.55	20.86	8.00	2.21	1.17	29.87	8.11	3.22	190.60	228.67	111.64	156.82	419.27	0.83	268.47	0.71	15.34	74.0	116.0	6.83	17.12	16.22	20.34	348.11
75	IL-155-1	1	2	53.0	67.0	129.86	53.12	19.06	2.68	1.11	1.27	39.00	10.88	4.41	97.70	127.56	35.11	47.45	225.26	0.77	82.55	0.74	14.39	77.0	124.0	31.00	38.00	12.64	13.92	528.80
76	IL-3168-A	2	2	44.0	67.0	164.31	129.02	22.43	8.00	2.21	0.78	60.48	9.68	4.87	149.19	194.02	37.54	64.01	343.21	0.77	101.55	0.59	14.60	80.0	142.0	30.05	41.00	8.43	11.78	482.78
77	IL-160-B	2	5	53.0	67.0	158.62	116.39	28.71	4.02	4.43	0.69	59.20	13.37	5.98	78.81	109.09	43.30	85.17	187.90	0.72	128.47	0.51	22.96	81.0	160.0	4.10	11.85	18.98	13.92	164.89
78	IL-886	2	2	51.0	67.0	114.07	41.32	18.62	2.68	2.21	1.17	59.56	13.55	8.09	108.51	187.98	41.97	90.03	298.49	0.58	132.00	0.47	16.93	70.0	141.0	1.37	6.58	9.48	10.70	70.47
79	IL-132	2	2	51.0	67.0	150.93	92.78	19.06	2.01	1.11	0.98	23.83	11.06	4.69	89.51	144.43	37.57	72.92	233.95	0.62	110.49	0.52	18.94	79.0	142.0	2.73	10.53	17.59	20.34	214.22
80	IL-160	3	2	51.0	67.0	150.93	99.16	23.89	2.01	2.21	0.88	22.54	6.27	3.40	97.92	152.75	47.98	68.45	250.67	0.64	116.43	0.70	17.04	80.0	140.0	5.46	13.17	14.74	19.27	253.68
81	IL-1155-B	2	2	81.0	90.0	225.65	188.06	20.19	8.00	2.21	0.98	48.33	7.50	2.84	72.59	308.81	32.74	133.93	381.40	0.24	166.67	0.24	18.94	124.0	142.0	5.46	14.48	18.98	21.41	310.06
82	IL-966	3	5	71.0	90.0	108.48	112.14	17.94	2.01	2.21	1.08	14.66	6.45	2.30	46.16	126.99	16.65	36.85	173.15	0.36	53.49	0.45	15.45	79.0	142.0	5.46	5.27	14.96	14.99	78.92
83	IL-144A	2	2	67.0	85.0	142.50	94.44	19.74	2.01	1.11	0.78	61.00	5.25	2.94	107.42	173.27	29.24	53.47	280.69	0.62	82.71	0.55	10.26	78.0	156.0	5.46	15.80	10.32	9.63	152.21
84	IL-3178	2	2	68.0	90.0	144.29	178.25	21.31	8.00	2.21	1.47	26.21	11.98	3.49	131.90	184.33	15.49	93.04	316.23	0.72	108.53	0.17	18.84	79.0	160.0	5.46	9.22	16.32	16.06	147.98
85	IL-160-A	2	3	63.0	71.0	131.66	119.23	22.43	8.00	4.43	1.08	37.20	12.17	3.95	61.56	219.33	118.24	89.84	280.89	0.28	208.08	1.32	14.92	82.0	142.0	1.37	7.90	11.37	10.70	84.56
86	HY-8-P-66	1	2	43.0	67.0	153.04	108.20	15.70	2.68	1.11	0.88	28.04	7.37	4.14	66.25	78.77	25.85	54.15	145.02	0.84	80.00	0.48	17.25	86.0	146.0	5.46	10.53	17.90	17.13	180.40
87	IL-2000-180	2	2	43.0	67.0	99.32	115.21	20.19	2.68	1.11	1.08	33.54	8.02	4.69	114.24	162.10	26.21	63.29	276.34	0.70	89.51	0.41	17.57	82.0	142.0	21.85	49.00	17.38	12.85	629.43
88	IL-2000-184	3	3	44.0	67.0	134.81	117.22	19.06	3.35	4.43	0.59	37.20	9.50	4.78	118.26	181.48	24.98	46.67	299.74	0.65	71.65	0.54	13.44	83.0	142.0	2.73	9.22	17.90	17.13	157.85
89	IL-2000-182	2	2	44.0	67.0	133.76	80.27	19.06	3.35	3.32	0.88	55.00	11.80	7.82	98.95	141.47	37.21	58.24	240.41	0.70	95.45	0.64	17.14	82.0	132.0	6.83	17.12	25.00	22.48	384.75
90	IL-2000-188	3	2	44.0	67.0	113.75	95.02	16.82	3.35	2.21	0.78	44.26	7.37	4.87	120.45	139.30	20.72	50.07	259.75	0.86	70.79	0.41	9.84	78.0	130.0	8.20	17.12	11.06	7.49	128.25

Highlights: : Higher values; : Lower values

Table B.1 Cont...

Trait Names – **1-EPV**: Early Plant Vigour; **2-PGH**: Plant Growth Habit; **3-D50F**: Days to 50% flowering; **4-DTF**: Days to Total Flowering; **5-PH**: Plant Height; **6-LMB**: Length of Main Branch; 7-NN: No. of Nodes; **8-NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; **14-LW/P**: Leaf Weight Per Plant; **15-SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; **22-100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table B.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➤	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
91	IL-2000-187	2	3	41.0	67.0	191.63	181.45	22.43	4.69	4.43	0.78	49.48	8.48	6.16	160.76	227.99	26.55	91.59	388.75	0.71	118.14	0.29	16.83	89.0	138.0	10.93	15.80	15.27	16.06	253.68
92	IL-2000-178	2	2	41.0	67.0	129.55	79.09	21.31	2.68	2.21	1.17	49.48	13.55	8.46	86.35	161.53	46.83	93.67	247.88	0.53	140.50	0.50	22.33	74.0	142.0	8.20	17.12	14.74	17.13	293.14
93	IL-2000-179	2	2	55.0	67.0	120.07	148.40	18.28	2.68	2.21	0.78	69.00	11.52	6.25	90.98	139.53	33.26	62.71	230.51	0.65	95.97	0.53	16.19	74.0	130.0	6.83	27.85	12.64	7.49	207.17
94	IL-2000-189	2	5	54.0	67.0	128.81	149.93	18.28	2.68	1.11	0.78	23.83	8.48	4.78	61.38	91.08	26.31	41.80	152.46	0.67	68.10	0.63	11.75	71.0	138.0	8.20	34.23	13.27	14.99	513.00
95	IL-2000-183	2	5	71.0	90.0	157.99	114.50	20.19	2.68	2.21	1.27	19.24	5.99	1.84	80.50	114.22	13.64	34.65	194.73	0.70	48.49	0.40	9.95	86.0	132.0	6.83	14.48	14.01	13.92	201.54
96	EC-244236A	2	5	71.0	90.0	161.46	148.89	20.86	2.01	3.32	1.08	37.57	9.22	4.32	106.44	171.79	26.76	72.98	278.23	0.62	99.74	0.37	15.24	118.0	142.0	9.56	17.12	12.22	11.76	201.54
97	IL-178-4	2	5	41.0	85.0	129.74	105.91	31.46	4.05	3.50	1.47	48.72	10.78	7.11	99.80	137.85	41.73	78.67	237.65	0.72	120.39	0.53	14.86	74.0	143.0	15.22	38.54	18.27	15.52	598.01
98	IL-390	1	5	44.0	80.0	62.67	229.46	14.52	5.40	3.50	1.35	57.24	11.36	6.98	91.28	109.35	41.25	90.76	200.63	0.83	132.01	0.45	12.93	121.0	126.0	4.68	16.16	14.14	11.36	183.90
99	IL-131	2	2	68.0	67.0	146.23	116.55	26.62	5.40	1.17	0.98	34.35	5.41	4.27	109.03	157.15	22.31	40.48	266.18	0.69	62.79	0.55	15.98	82.0	131.0	5.86	19.89	9.79	11.36	226.34
100	IL-853	1	5	50.0	100.0	113.91	115.76	24.20	4.05	1.17	0.74	29.26	6.30	4.14	100.28	125.21	17.67	33.38	225.49	0.80	51.05	0.53	16.19	129.0	146.0	7.03	17.41	14.47	16.55	288.07
101	IL-1053	2	2	64.0	97.0	114.68	238.28	18.15	4.05	4.00	0.86	25.44	4.79	3.49	95.78	242.43	15.10	61.72	338.21	0.40	76.82	0.24	19.55	115.0	135.0	5.86	18.65	12.94	15.52	289.36
102	IL_246	2	4	68.0	103.0	172.15	141.21	20.57	4.05	2.33	1.23	61.06	9.70	5.17	70.47	169.02	32.19	97.36	239.48	0.42	129.55	0.33	20.26	122.0	144.0	3.51	14.92	13.05	12.41	185.19
103	IL-3171	2	5	71.0	90.0	149.53	111.42	18.15	4.05	9.00	0.98	17.81	7.93	2.20	143.17	368.15	78.14	169.77	511.32	0.39	247.91	0.46	14.86	119.0	138.0	10.54	12.43	19.91	18.62	231.49
104	IL-380	2	5	71.0	90.0	134.14	120.58	20.57	5.40	2.33	1.23	31.29	9.07	2.84	63.41	137.63	27.42	64.03	201.04	0.46	91.45	0.43	14.35	120.0	134.0	9.37	11.19	19.04	17.58	196.76
105	IL-1057	1	2	43.0	67.0	223.86	120.58	32.67	9.44	1.17	1.23	73.78	15.51	6.20	114.28	138.85	66.91	82.99	253.13	0.82	149.90	0.81	18.43	117.0	120.0	12.88	30.00	20.67	21.72	651.65
106	IL-160-9	2	2	43.0	67.0	262.78	47.44	14.52	4.05	1.17	0.86	48.34	11.96	6.46	84.22	100.92	21.47	48.26	185.14	0.83	69.73	0.44	17.00	85.0	150.0	21.08	45.00	17.19	16.55	744.75
107	IL-622	2	5	68.0	90.0	130.40	98.85	20.57	5.40	2.33	1.35	43.63	12.34	6.20	70.47	136.52	43.30	105.72	206.99	0.52	149.01	0.41	17.61	120.0	149.0	18.74	42.27	15.23	14.48	612.15
108	IL-210	2	5	44.0	67.0	207.80	81.64	25.77	4.05	1.17	0.86	53.43	11.08	5.95	113.79	123.88	48.61	41.88	237.67	0.92	90.49	1.16	13.13	125.0	129.0	11.71	37.30	12.73	13.45	501.55
109	IL-3136-B	2	2	71.0	90.0	139.64	77.22	22.14	5.40	3.50	1.35	53.81	15.74	7.11	74.85	179.33	49.04	108.83	254.18	0.42	157.88	0.45	15.58	93.0	136.0	3.51	12.43	18.38	17.58	218.63
110	IL-892	2	2	71.0	90.0	84.99	146.33	20.57	2.70	4.00	0.86	16.54	5.41	2.33	133.60	234.12	79.83	172.22	367.71	0.57	252.05	0.46	20.16	121.0	136.0	2.34	7.46	12.51	14.48	108.03
111	IL-966-B	2	4	71.0	90.0	133.04	162.88	22.99	2.70	5.00	1.11	21.62	6.93	2.58	169.41	291.34	61.22	53.84	460.75	0.58	115.06	1.14	16.19	114.0	134.0	17.57	36.06	17.40	17.58	634.02
112	IL-1014-1	2	4	71.0	90.0	118.31	148.54	21.78	2.70	2.33	1.23	19.08	5.29	2.20	113.31	210.71	20.48	61.41	324.02	0.54	81.89	0.33	16.80	130.0	147.0	2.34	6.22	16.32	14.48	90.02
113	IL-416-4	2	5	68.0	90.0	118.75	82.74	21.78	4.05	1.17	1.23	25.44	7.30	2.84	128.15	204.84	23.48	55.75	332.99	0.63	79.24	0.42	16.70	131.0	137.0	3.51	7.46	14.14	13.45	100.31
114	IL-921	2	5	68.0	90.0	161.63	104.80	27.83	4.05	2.33	0.86	15.65	4.16	1.68	42.35	202.95	18.14	64.41	245.30	0.21	82.55	0.28	15.88	83.0	132.0	3.51	9.95	16.53	17.58	174.90
115	IL-360-A	3	5	68.0	90.0	134.47	76.45	22.99	5.40	2.33	0.98	24.17	7.93	2.58	87.75	137.85	15.61	62.87	225.60	0.64	78.48	0.25	15.58	88.0	154.0	4.68	8.70	13.81	16.55	144.04
116	IL-372	2	5	71.0	90.0	108.85	97.08	20.57	4.05	3.50	1.60	101.76	16.51	7.75	103.43	113.12	97.82	77.87	216.55	0.91	175.69	1.26	18.02	96.0	155.0	8.20	7.46	15.77	15.52	115.74
117	IL-419-1	2	5	44.0	67.0	153.93	147.44	25.41	1.35	1.17	0.98	34.35	9.70	6.46	78.99	143.18	22.82	83.80	222.16	0.55	106.62	0.27	18.22	83.0	142.0	16.39	38.54	19.58	14.48	558.14
118	IL-362	3	5	46.0	103.0	130.40	161.01	21.78	6.74	1.17	1.11	39.43	11.96	6.72	113.19	224.25	34.30	67.34	337.43	0.50	101.63	0.51	18.02	100.0	139.0	24.59	35.00	20.12	16.62	651.65
119	IL-812-1	2	5	44.0	67.0	112.15	176.45	18.15	6.74	1.17	0.98	31.80	9.07	4.91	146.41	157.15	34.51	36.66	303.56	0.93	71.17	0.94	19.34	96.0	140.0	12.88	41.00	17.30	14.48	593.73
120	IL-1050-3	2	5	68.0	90.0	116.55	116.94	18.15	5.40	2.33	1.23	37.27	7.81	4.65	90.43	235.34	31.71	76.76	325.76	0.38	108.46	0.41	12.73	97.0	138.0	3.51	6.22	15.99	13.45	83.59
121	IL-1177	2	5	68.0	92.0	139.32	114.78	19.21	3.67	6.50	1.28	30.21	7.30	5.19	187.39	594.22	128.29	413.51	781.61	0.32	541.80	0.31	15.08	93.0	135.0	2.92	7.18	14.36	11.39	81.73
122	IL-867	3	2	43.0	68.0	144.60	98.26	20.17	2.45	3.25	1.18	34.04	7.42	4.22	135.23	149.98	31.52	56.03	285.21	0.90	87.54	0.56	18.85	110.0	136.0	14.61	44.09	14.36	12.34	543.92
123	IL-161-1	1	1	46.0	68.0	124.65	93.94	21.42	4.89	1.63	0.75	56.93	6.91	5.13	91.05	93.90	30.49	66.34	184.95	0.97	96.83	0.46	8.83	123.0	132.0	4.87	26.66	10.80	12.34	328.88
124	IL_153-1	2	4	71.0	92.0	160.43	87.78	19.21	4.89	3.25	0.86	33.23	9.96	4.90	172.50	209.99	25.33	73.06	382.49	0.82	98.39	0.35	21.87	94.0	141.0	2.92	21.53	10.39	5.69	122.60
125	IL-812	2	2	68.0	92.0	123.49	88.86	16.33	2.00	1.00	1.07	38.69	6.40	1.37	22.41	41.94	19.16	32.79	64.35	0.53	51.94	0.58	12.39	126.0	135.0	4.87	6.15	11.00	9.49	56.38
126	IL-200	2	4	60.0	75.0	135.10	138.53	22.09	11.00	3.25	1.71	22.00	11.79	9.00	126.65	215.98	58.69	93.16	342.64	0.59	151.85	0.63	11.96	93.0	136.0	7.79	21.53	11.31	12.34	265.63
127	IL-893	2	4	49.0	68.0	144.60	133.89	17.29	6.11	3.25	1.18	70.87	13.52	12.53	139.59	119.48	60.82	71.83	259.07	1.17	132.65	0.85	21.44	99.0	136.0	7.79	24.61	15.28	14.23	350.29
128	IL-156	1	4	68.0	70.0	98.16	155.07	15.37	6.11	3.25	0.75	36.01	8.76	5.85	145.35	157.05	22.26	53.10	302.40	0.93	75.36	0.42	23.91	83.0	141.0	27.28	47.00	12.53	13.28	624.37
129	IL-1182	2	4	85.0	68.0	116.42	168.44	22.09	7.34	3.25	1.18	69.71	11.18	6.27	93.16	144.79	43.23	92.03	237.94	0.64	135.25	0.47	19.28	94.0	155.0	15.59	44.09	12.32	11.39	502.08
130	IL-4216	3	2	87.0	68.0	164.10	102.57	16.33	4.89	3.25	0.86	31.82	6.10	4.79	117.18	119.83	24.57	71.33	237.00	0.98	95.90	0.34	24.13	91.0	139.0	4.87	19.48	16.60	13.28	258.82
131	IL-380B	3	4	43.0	52.0	164.71	78.82	21.13	4.89	1.63	1.07	24.40	6.61	3.76	141.89	178.46	28.03	79.58	320.36	0.80	107.61	0.35	16.27	108.0	130.0	12.67	29.74	16.70	15.16	451.48
132	IL-1177-A	2	4	44.0	68.0	144.60	111.21	17.57	3.67	1.63	0.75	27.88	5.08	3.65	94.64	119.04	32.31	90.36	213.68	0.80	122.67	0.36	14.00	109.0	146.0	6.82	32.81	16.60	14.23	467.05
133	IL-380-C	2	4	68.0	80.0	129.82	97.16	17.29	6.11	4.88	0.96	59.00	7.83	6.27	263.57	324.31	219.86	199.05	587.88	0.81	418.91	1.10	13.79	109.0	142.0	2.92	11.28	14.36	12.34	139.14
134	IL-578-A	2	4	41.0	75.0	175.21	132.48	13.44	4.89	3.25	1.18	56.00	10.52	9.57	135.60	158.15	21.89	46.05	293.75	0.86	67.94	0.48	9.37	90.0	146.0	4.87	11.28	9.37	9.49	107.03
135	IL-370	2	2	71.0	92.0	108.71	122.10	15.37	4.89	3.25	1.18	66.47	8.44	5.70	109.18	99.40	31.18	82.51	208.58	1.10	113.69	0.38	14.33	120.0	152.0	4.87	16.41	15.99	14.23	233.53

Highlights: : Higher values; : Lower values

Table B.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table B.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➢	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
136	IL-1170-A	3	2	73.0	93.0	167.08	151.83	19.21	4.89	1.63	0.96	30.55	7.62	4.79	130.37	129.85	21.89	39.26	260.21	1.00	61.15	0.56	18.20	113.0	127.0	5.85	16.41	13.14	10.44	171.25
137	IL-1072-1-5	3	4	53.0	102.0	153.04	153.23	19.49	3.67	3.25	1.07	39.50	6.30	4.56	106.42	120.02	25.33	44.58	226.44	0.89	69.91	0.57	15.19	119.0	144.0	5.85	13.33	16.40	13.28	177.09
138	IL-419-2	2	2	51.0	62.0	116.10	152.91	13.44	3.67	1.63	0.75	49.00	4.78	1.48	107.57	196.54	50.76	93.42	304.11	0.55	144.18	0.54	18.10	83.0	139.0	9.74	25.64	19.56	16.13	413.53
139	IL-893-1	1	5	68.0	71.0	168.14	138.21	21.13	3.67	4.88	1.28	43.68	12.40	7.41	162.00	200.46	24.57	64.54	362.46	0.81	89.11	0.38	20.57	87.0	140.0	12.67	31.79	17.01	14.23	452.45
140	IL-14177-A	3	5	44.0	74.0	135.10	160.46	21.13	3.67	1.63	0.86	40.66	5.90	3.42	84.01	89.58	28.77	81.58	173.58	0.94	110.35	0.35	18.96	94.0	131.0	15.59	44.09	19.25	15.18	669.44
141	IL-1086-2	2	2	48.0	76.0	217.11	196.10	17.29	6.11	3.25	1.60	56.00	11.79	9.57	101.68	139.18	28.39	91.69	240.86	0.73	120.08	0.31	16.48	92.0	140.0	4.87	20.51	16.19	16.13	330.83
142	IL-155	3	5	43.0	69.0	156.53	157.23	16.33	3.67	1.63	0.96	54.60	7.32	5.70	176.60	208.52	37.47	61.75	385.12	0.85	99.22	0.61	10.34	84.0	127.0	9.74	32.81	9.37	9.49	311.37
143	IL-216-1	2	5	43.0	78.0	130.14	144.27	23.05	7.34	1.63	1.18	46.82	7.32	5.47	116.79	121.01	31.54	46.05	237.80	0.97	77.59	0.69	12.50	94.0	132.0	13.64	39.99	14.67	14.23	569.22
144	IL-887	2	2	44.0	79.0	200.54	167.27	21.13	6.11	3.25	0.86	32.59	4.57	3.08	97.20	111.28	32.40	45.91	208.48	0.87	78.32	0.71	16.91	96.0	137.0	7.79	30.76	14.36	15.18	467.05
145	IL-160-11	2	2	44.0	69.0	183.56	160.62	21.44	3.96	0.82	0.87	35.14	11.35	6.79	92.10	121.96	47.69	72.20	214.05	0.76	119.88	0.66	18.08	115.0	156.0	20.37	39.00	18.71	18.77	732.21
146	IL-1721	3	2	43.0	99.0	131.11	163.98	20.19	2.97	1.63	0.70	31.62	9.63	5.56	93.52	131.97	40.21	49.88	225.49	0.71	90.08	0.81	15.76	122.0	147.0	21.44	30.91	20.12	16.69	515.85
147	IL-3152-1	1	2	46.0	69.0	132.16	164.82	22.11	3.96	0.82	0.61	37.04	6.28	2.82	70.16	110.63	29.39	69.21	180.80	0.63	98.60	0.42	7.88	74.0	139.0	9.65	18.18	12.88	12.52	227.58
148	IL-3155	2	4	61.0	69.0	99.64	168.19	21.15	2.97	0.82	0.61	17.09	5.27	3.94	81.94	135.24	19.97	36.02	217.18	0.61	55.99	0.55	7.07	75.0	135.0	10.72	25.46	13.08	14.60	371.71
149	IL-18720-A	1	2	71.0	92.0	158.70	184.44	25.96	4.95	0.82	1.05	45.58	10.06	5.03	108.95	153.75	87.07	128.68	262.70	0.71	215.75	0.68	16.56	117.0	135.0	3.22	7.27	14.69	11.47	83.45
150	IL-3168-B	2	2	71.0	102.0	154.50	108.60	23.08	3.96	0.82	0.78	44.63	9.20	5.47	95.24	155.93	36.88	112.64	251.17	0.61	149.51	0.33	12.80	121.0	141.0	2.14	7.27	16.80	15.65	113.79
151	IL-632	2	2	44.0	69.0	138.77	181.07	22.11	4.95	2.45	0.78	67.43	10.58	5.91	50.67	79.92	21.47	58.13	130.59	0.63	79.60	0.37	14.50	83.0	138.0	6.43	16.36	13.38	10.43	170.68
152	IL-1156-1	2	5	58.0	61.0	148.21	160.03	21.15	2.97	1.63	0.70	28.20	4.13	1.94	73.72	111.29	28.51	59.14	185.00	0.66	87.66	0.48	16.11	75.0	146.0	15.01	34.55	19.01	15.65	540.50
153	IL-1177-B	2	5	71.0	92.0	120.62	170.13	20.19	1.98	2.45	0.78	20.23	6.19	2.38	78.69	131.87	25.07	76.15	210.56	0.60	101.23	0.33	11.73	74.0	140.0	23.59	42.00	16.10	16.69	700.92
154	EC-24102-1	2	5	58.0	69.0	123.77	144.62	21.15	4.95	4.08	0.96	46.53	9.63	5.56	99.41	156.91	44.78	89.60	256.32	0.63	134.38	0.50	14.77	74.0	144.0	27.87	45.00	17.81	15.65	704.05
155	RAJL-2	1	2	58.0	69.0	113.59	104.39	12.79	4.95	2.45	0.70	28.49	4.47	1.59	73.82	143.95	22.61	62.45	217.77	0.51	85.06	0.36	9.04	83.0	132.0	4.29	14.55	13.08	10.43	151.72
156	IL-1063	3	2	61.0	69.0	138.77	162.30	20.19	3.96	0.82	0.70	32.29	6.19	3.35	58.18	117.71	29.03	81.62	175.89	0.49	110.66	0.36	11.28	83.0	139.0	5.36	11.82	12.57	11.47	135.60
157	IL-182	3	5	41.0	69.0	126.92	172.40	17.31	4.95	1.63	0.78	40.83	6.62	4.15	57.78	99.85	33.87	49.55	157.63	0.58	83.43	0.68	13.43	75.0	149.0	3.22	12.73	16.10	17.73	225.68
158	RAJL-16	1	2	59.0	69.0	104.89	107.17	11.54	3.96	4.08	0.52	28.49	5.33	2.91	71.89	124.68	26.31	47.86	196.57	0.58	74.17	0.55	6.54	75.0	132.0	5.36	12.73	15.89	16.69	212.41
159	IL-200-186	3	5	43.0	69.0	139.82	115.15	10.23	3.96	1.00	0.70	16.14	2.84	2.38	34.32	83.37	21.03	35.78	117.69	0.41	56.81	0.59	17.90	76.0	142.0	6.43	13.64	15.89	13.56	184.91
160	IL-14	1	4	68.0	92.0	130.06	180.82	20.19	2.97	5.71	0.78	24.69	6.28	2.38	94.53	153.53	27.19	53.90	248.07	0.62	81.09	0.50	16.38	78.0	137.0	5.36	7.27	16.10	17.73	128.96
161	IL-3192	2	2	44.0	69.0	171.28	134.52	22.40	0.99	3.26	0.52	11.68	12.62	9.73	87.73	138.29	32.85	43.45	226.02	0.63	76.29	0.76	12.71	107.0	138.0	5.36	11.82	11.07	11.47	135.60
162	IL-3177	2	2	68.0	92.0	122.72	190.92	12.50	2.97	0.82	0.52	11.02	4.90	2.88	88.44	163.55	43.02	77.32	251.99	0.54	120.34	0.56	10.30	108.0	132.0	8.58	5.45	14.08	15.65	85.34
163	IL-3157	2	2	44.0	69.0	213.24	174.09	22.11	3.96	1.63	0.87	34.47	8.86	3.09	78.79	140.79	24.02	68.97	219.59	0.56	92.99	0.35	11.28	76.0	138.0	12.87	32.00	16.10	18.77	600.79
164	IL-160-C	3	4	69.0	76.0	124.08	134.52	18.27	0.99	4.08	0.61	13.58	4.30	1.59	88.24	121.30	46.36	75.38	209.54	0.73	121.75	0.62	10.47	75.0	134.0	5.36	11.82	10.06	8.34	98.62
165	IL_892	2	5	69.0	76.0	155.55	169.03	21.15	2.97	4.00	0.87	62.68	9.03	3.62	128.45	222.24	37.39	67.44	350.69	0.58	104.83	0.55	15.31	76.0	142.0	3.22	3.64	13.08	11.47	41.72
166	IL-449	2	5	58.0	92.0	112.23	153.04	18.27	0.99	6.52	0.61	33.52	10.75	4.94	154.34	262.75	119.09	126.67	417.09	0.59	245.76	0.94	17.10	76.0	140.0	7.50	22.73	15.69	14.60	331.89
167	IL-1471	2	2	41.0	92.0	150.31	141.44	22.11	3.96	5.00	0.78	46.82	8.17	3.70	156.98	285.29	24.81	52.54	442.27	0.55	77.35	0.47	14.68	76.0	138.0	10.72	30.00	16.40	16.69	500.67
168	IL-4170	2	4	41.0	92.0	105.94	147.33	20.19	2.97	1.63	0.78	30.39	4.73	2.65	105.09	125.22	27.80	48.99	230.32	0.84	76.79	0.57	11.19	116.0	138.0	5.36	13.64	15.09	15.65	213.36
169	BL-1	2	2	65.7	76.7	150.89	97.89	22.47	3.43	2.14	0.93	49.76	11.70	6.66	83.13	139.26	42.64	93.01	222.39	0.60	135.66	0.46	15.14	85.9	135.3	9.57	21.86	15.00	15.43	337.22
170	BL-2	2	2	47.6	81.4	130.09	79.37	18.17	4.14	1.71	0.96	29.43	8.56	4.19	80.10	144.31	29.70	70.88	224.41	0.56	100.58	0.42	16.55	97.3	136.7	7.29	25.00	12.79	13.00	325.00
171	UPC-5286	2	3	69.1	90.0	131.13	114.33	18.00	3.71	2.86	1.04	42.09	11.54	4.87	82.07	183.13	30.77	78.09	265.20	0.45	108.86	0.39	16.60	103.1	139.7	7.71	15.00	15.47	13.43	201.43
172	IGFRI-95-1	2	1	45.4	66.4	156.86	69.64	16.19	3.19	1.57	1.14	38.76	7.23	5.27	65.44	137.50	21.25	56.06	202.94	0.48	77.31	0.38	11.80	82.7	121.6	16.57	31.00	11.30	12.14	376.43

Highlights: : Higher values; : Lower values

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Appendix C

Table C.1 Morphological traits of the evaluated germplasm lines pooled for the years 2004-05 and 2005-06

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➤	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	Hy10-36-4	1	1	44.5	61.5	195.42	166.31	25.33	5.64	2.29	1.47	85.42	14.44	7.64	234.20	315.80	119.85	185.49	550.01	0.71	305.34	0.71	16.26	76.0	126.0	9.27	21.28	17.39	15.08	337.26
2	EC-48720	2	2	44.0	74.0	187.32	182.31	21.07	5.17	10.50	1.24	122.05	9.65	10.29	215.59	369.34	87.29	201.11	584.93	0.56	288.40	0.54	13.71	87.0	136.0	3.10	6.81	13.63	13.93	92.06
3	IVM-1	2	1	72.0	89.0	148.06	124.80	27.13	6.27	3.14	1.53	82.48	14.07	9.08	154.55	246.30	66.22	140.60	400.85	0.66	206.82	0.50	15.45	105.0	136.0	5.16	9.73	12.98	12.87	116.42
4	EC-244310	2	4	42.0	77.0	120.47	142.56	20.68	5.48	13.00	1.14	76.19	8.74	6.70	80.93	252.08	40.48	133.93	333.02	0.31	174.41	0.34	7.64	105.0	116.0	4.13	6.74	11.99	10.74	74.11
5	EC-240564	2	5	41.0	61.5	145.73	157.48	24.08	5.48	13.00	1.28	62.41	9.48	7.44	137.38	262.71	51.72	122.28	400.10	0.50	174.01	0.55	15.87	76.0	121.0	3.09	12.35	15.28	11.97	155.48
6	EC-244979	2	5	41.5	71.5	177.94	175.40	18.88	4.71	2.42	1.05	57.63	10.18	6.20	142.69	207.44	51.27	110.99	350.14	0.68	162.26	0.45	13.42	76.0	113.0	4.12	13.48	15.75	12.87	177.25
7	EC-240887	3	5	42.5	55.5	124.76	174.58	16.94	5.81	3.14	1.10	61.77	13.01	7.11	109.46	266.88	48.18	167.92	376.34	0.40	216.09	0.32	14.79	62.0	136.0	8.24	34.95	16.37	15.90	555.79
8	HY10P527	2	2	47.0	64.0	115.34	189.42	18.11	3.77	1.57	1.12	37.55	9.71	5.44	57.75	133.12	27.06	72.85	190.87	0.43	99.92	0.38	8.62	75.0	137.0	4.13	7.94	10.90	11.47	94.29
9	HY6P52-3	2	5	47.5	64.0	166.22	119.74	22.07	7.23	5.55	1.22	90.93	14.65	8.27	194.09	186.78	84.75	112.53	380.87	1.04	197.28	0.78	11.36	75.0	132.0	3.10	23.58	13.64	16.15	393.35
10	EC-240884	3	5	42.5	64.5	144.77	71.32	18.19	4.24	2.29	0.94	43.62	12.75	6.60	121.22	201.74	57.23	94.70	322.96	0.60	151.93	0.62	15.77	80.0	115.0	5.16	13.52	16.22	13.93	189.85
11	EC-244236	2	5	48.0	64.0	130.80	136.99	20.38	7.54	7.00	1.33	97.75	13.41	6.49	137.49	217.36	57.79	123.84	354.84	0.63	181.63	0.52	16.06	105.0	134.0	6.18	10.13	13.31	14.02	144.56
12	NP-3-14-A	3	5	44.0	61.0	122.10	134.72	14.21	4.24	1.57	1.27	35.07	9.02	5.75	104.59	183.74	43.77	78.27	288.33	0.54	120.04	0.54	14.11	73.0	130.0	4.12	10.09	11.99	10.74	112.04
13	HY6P52-10	2	5	41.5	59.5	142.74	158.85	16.94	4.87	2.29	1.26	33.80	9.18	5.80	89.36	153.47	38.85	64.91	242.84	0.57	103.77	0.58	15.19	70.0	121.0	8.24	24.71	15.28	12.95	331.58
14	HY6P52-9	3	5	69.0	81.0	142.89	166.95	25.19	5.83	8.93	1.32	105.68	13.16	7.82	131.75	284.13	70.77	141.62	415.88	0.49	212.29	0.50	16.07	89.0	135.0	2.07	4.48	14.18	12.87	59.70
15	HY-10P583	3	5	47.5	64.0	134.52	133.01	18.66	7.07	7.00	1.30	112.23	12.65	7.77	186.22	257.10	73.24	146.63	443.32	0.74	219.87	0.48	13.32	75.0	128.0	3.10	25.84	14.66	17.13	451.36
16	EC120001	3	5	43.0	60.0	196.73	94.77	23.57	6.13	3.26	1.50	78.15	14.53	9.24	164.48	201.66	61.76	94.83	366.14	0.80	156.60	0.61	15.97	80.0	133.0	4.13	12.43	16.91	17.38	214.51
17	EC241023	3	5	70.0	81.0	124.50	147.13	19.59	6.91	11.22	1.37	117.89	13.20	7.11	157.43	267.63	66.48	147.89	425.06	0.56	214.37	0.42	14.94	89.0	133.0	3.11	7.91	17.55	16.15	126.82
18	EC244223-1	2	5	47.5	62.5	153.24	174.90	18.19	6.13	5.43	1.23	79.01	12.62	11.00	140.25	197.00	61.84	97.79	337.25	0.75	159.64	0.64	10.86	75.0	136.0	4.10	12.24	13.19	12.87	168.36
19	NP-3-7	2	2	57.0	62.5	199.54	143.58	25.35	5.34	3.74	1.16	74.64	14.03	8.07	203.11	291.76	92.29	139.01	494.87	0.66	231.30	0.55	20.17	75.0	121.0	10.32	27.84	21.84	15.08	457.76
20	EC-240714	2	2	44.5	59.5	119.31	103.77	18.59	4.87	2.29	1.22	48.72	12.93	7.57	110.03	195.18	45.79	93.84	305.21	0.56	139.63	0.49	15.09	71.0	116.0	8.20	21.43	19.71	15.90	340.73
21	EC-244243	2	5	72.0	89.0	116.81	107.59	19.59	5.81	6.88	1.56	95.56	9.89	6.61	123.50	306.36	62.83	177.12	429.87	0.38	239.94	0.35	15.61	105.0	131.0	14.44	29.19	14.70	13.77	401.91
22	EC-240840	2	5	72.0	89.0	164.71	160.51	23.55	5.50	5.31	1.57	69.86	11.69	7.01	76.08	192.33	38.41	133.26	268.41	0.44	171.67	0.29	15.33	105.0	135.0	10.30	23.69	15.20	15.98	378.99
23	NP-3-10	2	2	43.0	55.0	113.00	115.82	20.30	7.07	4.59	1.32	97.11	13.57	8.83	189.26	237.00	72.52	109.23	426.26	0.78	181.75	0.64	17.63	60.0	131.0	4.13	7.84	10.89	17.13	138.99
24	EC-244249	2	5	53.5	62.5	163.20	152.29	15.16	4.56	1.57	0.96	40.78	11.34	6.81	92.56	136.45	45.51	72.61	229.01	0.67	118.13	0.63	15.58	75.0	135.0	4.13	21.17	17.47	16.06	359.36
25	HY-5P-6S-215	2	5	41.5	50.5	123.67	117.03	18.71	5.32	2.98	1.26	43.01	14.14	6.91	143.35	206.84	73.87	101.84	350.20	0.68	175.71	0.67	16.57	65.0	131.0	12.25	21.02	14.59	13.09	275.67
26	EC-244217	2	2	57.0	66.5	169.19	129.30	21.24	6.70	7.82	1.07	101.44	13.09	7.96	149.18	294.61	63.76	148.16	443.78	0.49	211.92	0.36	19.03	90.0	131.0	4.10	8.76	10.70	10.16	87.66
27	IVM	2	1	77.0	95.0	130.96	88.69	22.76	6.39	2.52	1.35	86.09	9.18	5.59	93.14	200.96	40.80	120.85	294.10	0.46	161.66	0.36	17.83	117.0	136.0	5.09	7.88	14.10	16.06	127.67
28	EC-240998	2	2	70.5	82.0	153.30	144.03	22.10	5.32	4.12	1.36	63.17	10.49	4.87	74.90	232.81	41.80	124.28	307.71	0.31	166.08	0.32	15.32	90.0	146.0	5.08	8.76	11.67	12.08	107.06
29	EC-240650	2	2	61.5	60.0	145.33	153.95	22.91	5.34	2.52	1.01	63.64	14.16	8.60	128.58	203.86	58.11	80.36	332.44	0.62	138.47	0.64	16.31	70.0	131.0	5.09	11.39	11.67	12.08	137.84
30	RA-2	3	4	82.0	83.5	132.43	90.89	20.73	5.30	3.66	0.99	106.69	5.80	4.50	91.13	246.60	53.45	180.23	337.73	0.33	233.68	0.27	10.34	117.0	132.0	7.16	20.15	10.70	12.08	244.89
31	EC-240999	3	5	70.5	94.5	145.08	156.81	23.77	6.95	5.44	1.28	73.68	3.72	2.45	55.17	219.37	33.10	157.33	274.53	0.25	190.43	0.21	16.96	117.0	132.0	5.12	6.13	15.76	13.09	80.52
32	UPC-870	2	5	66.5	70.0	194.92	177.05	19.07	6.91	3.05	1.21	53.31	8.90	6.36	81.18	211.93	46.55	94.25	293.10	0.38	140.80	0.51	14.06	90.0	132.0	7.16	7.88	15.55	15.11	119.29
33	HY-10-P-10-2-4	3	5	66.0	82.0	234.95	195.45	17.59	7.45	4.58	1.26	72.20	12.47	7.03	108.29	249.17	54.34	144.76	357.46	0.41	199.10	0.39	22.02	90.0	120.0	11.22	17.52	14.58	13.09	229.82
34	RAJL-4	2	5	56.0	72.5	166.44	102.18	16.69	3.72	1.99	0.76	57.14	10.80	4.71	95.17	143.19	56.19	69.08	238.36	0.68	125.26	0.81	9.74	75.0	134.0	8.15	18.40	11.68	10.05	185.78
35	NP-3-8	2	5	67.0	80.0	192.80	147.51	21.62	6.91	7.96	1.21	50.47	12.21	5.90	53.17	202.35	29.42	121.41	255.52	0.26	150.84	0.24	15.93	90.0	121.0	4.07	3.50	10.69	11.06	39.50
36	EC-240800	3	5	41.5	56.0	144.23	119.14	17.34	5.30	3.60	1.15	66.31	10.57	6.79	130.24	244.06	62.12	121.29	374.29	0.53	183.41	0.51	16.57	76.0	135.0	12.25	26.28	14.88	13.09	344.19
37	EC-240740	3	5	43.5	56.5	116.80	93.36	17.19	4.25	2.60	1.15	55.58	9.22	5.87	93.17	141.68	37.41	88.37	234.84	0.65	123.79	0.42	16.77	76.0	126.0	5.09	18.40	13.62	12.08	222.46
38	EC-244217-1	2	5	43.0	55.5	154.99	137.31	19.37	4.23	2.59	1.28	51.03	10.58	6.58	96.67	206.77	43.56	114.92	303.44	0.45	158.48	0.59	13.14	76.0	128.0	11.22	28.03	13.60	16.12	451.98
39	NP-3-14-B	3	5	61.0	75.0	183.01	160.47	21.74	4.79	3.98	1.16	66.20	13.76	8.68	143.67	247.73	67.09	116.61	391.39	0.57	183.60	0.58	16.81	76.0	133.0	4.11	17.52	14.79	13.09	229.82
40	EC-240842	2	5	77.0	95.5	161.95	96.68	15.17	2.59	2.45	0.81	22.66	6.32	3.93	26.10	81.65	17.38	46.96	107.95	0.32	64.37	0.43	20.27	117.0	146.0	4.10	5.26	15.17	15.11	79.58
41	Local-3	2	5	40.0	56.0	171.27	138.66	15.68	5.86	5.72	1.26	86.75	13.46	6.72	152.73	246.39	75.76	117.72	399.12	0.61	193.49	0.55	18.77	76.0	136.0	12.25	21.02	11.21	8.09	168.88
42	Local-2	2	5	65.0	75.0	201.84	102.74	16.54	5.70	2.45	0.70	26.30	9.14	5.79	39.22	114.89	20.91	68.51	154.11	0.36	87.42	0.33	18.22	90.0	131.0	9.18	13.14	21.71	22.17	291.16
43	Local-1	2	5	46.0	63.0	231.15	117.74	17.85	4.65	1.92	0.96	39.70	12.32	6.75	77.07	112.23	42.36	85.69	189.30	0.68	128.05	0.55	16.89	76.0	121.0	8.16	8.76	24.62	21.14	184.90
44	NP-3-7-1	3	5	46.0	55.0	183.30	145.29	25.44	4.25	1.53	1.10	51.11	11.60	6.48	119.43	254.45	48.31	93.12	373.88	0.46	141.42	0.49	18.23	76.0	121.0	7.14	17.52	15.76	13.09	229.55
45	HY-5p-32-2b	2	5	43.0	65.0	160.32	116.61	16.69	4.78	3.52	1.21	45.75	10.18	7.31	117.53	213.52	50.00	88.77	331.05	0.54	138.77	0.52	15.27	80.0	131.0	4.07	13.14	15.36	17.13	225.17

Highlights: : Higher values; : Lower values

Table C.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table C.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➤	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
46	EC-24077	2	5	70.5	82.0	179.10	161.01	26.14	5.84	6.71	1.51	97.39	12.24	6.80	112.91	286.04	55.39	152.93	398.95	0.45	208.32	0.41	17.08	90.0	138.0	3.05	8.76	15.07	15.11	132.70
47	NP-652-Y	3	5	49.0	65.0	198.03	156.57	20.58	5.17	1.92	1.32	47.82	12.43	7.32	124.26	240.11	46.38	83.97	364.37	0.51	130.35	0.52	16.08	76.0	131.0	9.18	13.14	12.65	12.13	158.82
48	IL-99-69	2	5	56.0	65.0	208.65	203.11	20.38	6.89	4.58	1.72	90.23	10.97	6.62	170.48	282.19	69.27	115.87	452.66	0.54	185.14	0.63	12.06	76.0	141.0	15.30	34.16	12.83	13.09	448.17
49	EC-241037	1	5	70.0	84.0	173.67	156.44	23.49	4.72	5.34	1.33	134.65	11.69	6.65	168.67	330.39	98.40	177.53	499.06	0.53	275.93	0.62	14.05	117.0	141.0	3.92	3.46	15.57	13.97	49.59
50	EC240898	2	5	53.0	65.5	160.03	104.50	18.37	3.99	4.32	0.98	68.34	8.93	5.52	110.97	189.98	52.30	69.49	300.95	0.61	121.79	0.68	19.13	81.0	138.0	3.92	9.38	11.87	9.97	91.94
51	HY-6P-05-28	2	5	51.0	65.0	153.71	145.03	21.94	6.12	4.94	1.24	68.48	10.09	5.68	112.07	227.06	59.29	88.69	339.13	0.54	147.97	0.65	14.06	79.0	141.0	3.92	8.53	14.60	13.97	120.99
52	EC-240782	3	5	45.0	61.5	161.13	140.05	18.47	4.26	2.78	1.13	57.65	9.72	6.76	117.30	175.92	61.73	70.89	293.22	0.70	132.62	0.88	18.44	61.0	146.0	4.89	9.60	14.11	14.97	148.46
53	IL-181	2	5	80.0	104.5	166.13	113.69	21.13	6.85	2.78	1.25	79.44	14.10	9.29	160.78	209.65	75.34	95.66	370.44	0.81	171.00	0.76	25.24	73.0	118.0	3.86	10.30	12.65	7.99	85.02
54	IL-792	2	1	51.0	63.5	143.90	110.24	17.75	4.29	2.88	1.13	95.16	11.64	8.47	129.38	192.50	75.70	86.76	321.88	0.83	162.46	0.94	8.98	76.0	122.0	11.64	16.99	8.57	8.97	150.22
55	IL-179	3	1	52.5	63.5	156.51	160.13	15.30	4.72	4.42	0.93	60.39	9.22	6.16	70.71	139.99	37.65	62.14	210.70	0.50	99.78	0.68	10.10	76.0	131.0	16.53	32.36	10.70	10.98	361.21
56	IL-90	3	1	53.0	63.5	171.05	128.87	25.27	6.53	2.26	1.35	90.40	11.52	8.53	127.19	176.36	59.43	88.01	303.55	0.74	147.44	0.65	10.77	76.0	133.0	24.38	46.89	10.71	10.98	523.94
57	IL-178-8	2	3	51.0	64.0	146.64	140.76	25.77	6.85	5.66	0.98	81.08	13.35	8.66	126.65	193.56	38.32	82.91	320.21	0.68	121.23	0.48	21.02	77.0	136.0	4.89	4.30	11.68	10.99	49.83
58	EC-240809	2	3	52.5	64.0	153.98	173.34	22.67	4.59	2.26	1.14	54.23	10.34	7.06	118.39	202.46	55.57	73.58	320.85	0.62	129.15	0.77	15.02	77.0	134.0	19.36	36.44	19.26	16.96	622.86
59	IL-55-1	3	4	56.0	64.0	133.04	139.13	18.68	7.86	5.98	1.30	89.25	11.02	9.17	70.49	107.78	46.69	58.96	178.27	0.66	105.65	0.78	15.02	77.0	141.0	8.75	10.22	17.02	17.96	185.64
60	IL-177	2	4	51.0	63.5	203.74	157.32	20.48	4.26	2.78	0.88	36.45	9.46	6.19	48.22	104.91	26.93	69.13	153.13	0.46	96.06	0.40	19.40	77.0	141.0	5.72	16.99	15.57	15.97	273.93
61	RAJ-2	3	1	57.0	63.5	178.65	120.16	22.26	3.66	3.40	0.98	40.00	9.74	5.59	45.88	107.80	29.73	50.94	153.68	0.42	60.67	0.60	8.94	77.0	126.0	4.89	16.15	10.23	9.97	158.82
62	IL-99-40	3	1	51.0	83.5	186.74	131.85	19.66	3.40	2.26	1.04	31.57	12.58	8.36	43.02	96.87	30.30	61.69	139.69	0.44	91.99	0.52	10.68	77.0	124.0	9.71	23.06	13.63	12.97	304.24
63	IL-99-38	3	1	50.5	62.0	156.12	182.06	15.20	1.99	2.16	0.82	30.72	10.50	7.32	45.77	86.66	32.76	44.30	132.42	0.53	77.05	0.73	10.74	77.0	123.0	7.78	16.84	11.68	9.98	168.82
64	IL-99-34	2	1	51.5	62.0	145.49	166.67	25.35	4.26	3.40	1.14	85.17	12.83	7.20	81.73	136.68	46.92	67.53	218.41	0.59	114.45	0.69	10.66	75.0	121.0	7.78	16.84	11.68	9.48	160.02
65	IL-99-98-1	3	4	59.5	75.5	150.49	124.40	17.81	4.12	3.29	0.83	54.99	8.44	5.65	115.80	151.46	77.45	70.43	267.27	0.73	147.88	0.97	14.30	77.0	126.0	4.89	10.22	11.68	9.97	100.30
66	IL-99-98	3	4	57.0	78.5	137.81	157.84	15.12	3.06	2.16	0.88	37.07	6.79	8.36	40.16	100.25	25.19	58.60	140.40	0.40	83.79	0.43	10.91	77.0	120.0	5.85	8.53	9.94	11.98	103.94
67	IL-99-73	3	4	52.5	65.0	160.36	80.03	23.56	4.12	2.78	0.93	55.84	11.01	7.31	76.95	116.10	48.83	58.62	193.05	0.69	107.45	0.86	12.46	77.0	117.0	6.82	17.22	12.17	9.97	167.10
68	IL-99-2	3	4	53.0	65.0	190.43	110.08	23.16	5.32	4.42	1.30	75.18	12.66	8.09	97.75	169.36	63.56	84.17	267.12	0.60	147.73	0.89	11.81	77.0	120.0	7.78	22.99	11.19	8.98	210.50
69	IL-99-72	3	4	52.0	62.0	224.14	127.47	17.31	3.66	2.16	1.09	32.36	11.37	7.95	60.77	119.67	26.97	58.13	180.44	0.52	85.10	0.46	9.02	77.0	113.0	6.82	41.97	12.65	11.98	513.16
70	IL-99-65	2	4	46.0	65.5	197.67	114.23	20.33	3.80	2.26	0.93	43.97	11.93	7.38	82.60	173.29	44.77	60.82	255.89	0.48	105.60	0.73	10.09	77.0	115.0	5.72	25.45	9.74	8.98	231.96
71	IL-01-88	2	5	46.5	60.0	198.89	103.42	17.64	6.12	4.42	1.08	56.79	10.44	5.41	108.14	214.57	42.77	75.88	322.71	0.53	118.66	0.60	15.85	75.0	144.0	4.31	7.84	11.68	11.99	103.91
72	IL-99-171	3	5	47.5	63.0	231.73	152.21	19.91	4.59	2.78	0.98	45.79	11.54	7.69	94.35	128.41	42.24	63.16	222.76	0.95	105.40	0.64	13.43	79.0	116.0	11.64	27.14	14.11	15.97	437.00
73	IL-3117	1	2	47.0	65.0	177.34	100.62	28.68	4.68	2.10	1.08	64.51	9.21	6.39	132.74	191.04	60.66	86.22	323.78	0.70	146.88	0.73	18.75	78.0	131.0	17.85	44.67	14.32	16.24	725.40
74	IL-15-1	2	2	54.5	74.0	137.52	171.24	20.26	8.20	2.66	1.22	62.44	10.45	6.25	225.14	265.94	113.67	161.17	491.07	0.84	274.84	0.71	14.42	73.0	138.0	8.25	16.73	14.53	18.38	308.26
75	IL-155-1	1	2	52.0	65.5	161.48	107.39	20.91	5.02	1.07	1.32	61.61	11.64	5.89	144.36	221.04	88.88	95.65	365.40	0.69	184.53	0.87	13.57	74.0	122.0	30.69	48.50	12.25	12.27	577.91
76	IL-3168-A	2	2	47.5	65.5	167.17	95.66	20.53	7.68	2.14	1.08	95.02	11.48	6.32	175.36	227.66	65.01	96.71	403.02	0.77	161.72	0.65	13.73	79.0	131.0	28.83	53.19	11.13	10.24	525.59
77	IL-160-B	2	5	52.0	65.5	155.81	144.59	23.15	5.69	4.28	1.13	67.39	12.40	7.02	102.48	153.74	55.56	104.84	256.23	0.68	160.39	0.53	18.34	79.0	136.0	5.50	14.10	15.41	12.27	169.29
78	IL-886	2	2	46.5	61.0	130.69	89.42	18.62	5.54	3.18	1.37	74.59	12.30	8.03	124.33	211.72	50.79	97.65	336.04	0.59	148.45	0.52	16.51	70.0	136.0	1.37	5.52	9.18	9.22	52.46
79	IL-132	2	2	51.0	65.0	162.19	122.63	18.84	4.16	2.62	1.22	69.14	11.59	6.88	125.34	201.27	59.40	98.13	326.61	0.62	157.53	0.59	18.00	78.0	138.0	4.13	9.72	16.35	17.42	171.70
80	IL-160	3	2	51.0	65.5	167.87	139.33	20.74	5.73	2.14	1.18	52.30	9.72	6.29	161.08	251.40	83.76	130.93	412.48	0.64	214.70	0.66	16.40	79.0	136.0	5.49	15.50	14.29	16.40	247.41
81	IL-1155-B	2	2	81.5	96.5	212.95	200.35	21.47	6.63	5.76	1.03	127.27	7.87	5.20	125.42	366.49	53.98	248.22	491.91	0.33	302.20	0.23	16.11	118.0	146.0	5.49	13.93	17.38	17.47	245.45
82	IL-966	3	5	61.0	76.5	146.81	139.58	20.35	5.21	2.66	1.13	39.72	8.99	5.79	60.77	164.29	31.54	76.60	225.06	0.37	108.14	0.43	14.53	78.0	146.0	4.11	7.09	13.50	13.29	91.13
83	IL-144A	2	2	60.0	73.5	150.76	142.16	20.73	4.16	2.62	1.13	89.88	8.10	6.06	130.82	208.57	57.70	92.14	339.40	0.63	149.83	0.60	10.37	77.0	138.0	4.11	15.33	10.69	10.13	155.05
84	IL-3178	2	2	59.5	76.5	178.35	152.54	23.07	8.20	6.28	1.57	106.50	11.51	6.94	188.58	261.52	64.64	142.84	450.11	0.72	207.49	0.38	18.01	78.0	145.0	5.49	11.29	15.32	14.31	157.96
85	IL-160-A	2	3	57.0	67.0	144.60	119.61	24.15	8.20	5.32	1.37	75.83	11.99	7.02	157.83	248.54	112.77	118.77	406.37	0.60	231.54	1.02	14.00	78.0	131.0	1.37	6.92	11.71	9.22	65.25
86	HY-8-P-66	1	2	47.0	65.5	125.76	107.90	19.23	4.49	2.62	1.22	52.35	9.35	6.05	104.09	122.47	48.78	67.38	226.56	0.85	116.16	0.68	16.35	79.0	146.0	4.11	8.24	15.37	15.33	130.39
87	IL-2000-180	2	2	44.0	65.0	132.18	134.17	21.47	6.07	4.17	1.27	71.83	10.40	6.93	150.84	213.29	70.41	115.91	364.14	0.71	186.31	0.55	16.56	79.0	146.0	20.59	50.50	15.85	11.25	565.90
88	IL-2000-184	3	3	44.5	65.0	160.72	156.75	19.88	5.88	5.32	1.03	83.38	11.38	7.28	153.85	236.73	67.31	111.51	390.58	0.65	178.82	0.58	12.39	78.0	136.0	5.51	8.32	16.36	15.33	129.16
89	IL-2000-182	2	2	47.5	65.0	171.21	131.33	19.36	4.30	3.73	1.03	57.73	11.28	7.64	82.75	147.33	42.11	73.64	230.08	0.57	115.74	0.58	16.29	78.0	141.0	8.25	16.73	24.35	19.45	326.58
90	IL-2000-188	3	2	47.5	65.5	163.08	95.06	19.28	5.88	3.69	0.88	69.64	9.26	6.47	124.20	143.06	38.73	62.07	267.25	0.87	100.80	0.59	9.62	79.0	131.0	6.86	16.73	9.83	8.09	135.18

Highlights: : Higher values; : Lower values

Table C.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.

Table C.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
91	IL-2000-187	2	3	41.0	60.5	174.76	185.98	20.53	6.02	4.28	0.93	55.51	10.92	8.38	128.90	191.42	35.82	90.71	320.31	0.67	126.54	0.40	15.16	69.0	136.0	6.84	15.33	13.81	13.34	205.79
92	IL-2000-178	2	2	47.5	67.0	206.59	86.40	19.45	3.44	3.18	1.22	49.03	13.65	9.73	101.00	191.23	55.64	106.35	292.23	0.53	162.00	0.52	20.02	72.0	146.0	5.48	16.73	13.79	14.36	241.30
93	IL-2000-179	2	2	55.0	67.5	156.41	136.17	19.49	5.02	5.76	1.08	78.23	11.24	7.61	107.67	157.69	51.69	80.75	265.36	0.68	132.44	0.62	14.85	73.0	132.0	5.49	27.94	11.46	8.09	226.31
94	IL-2000-189	2	5	48.0	61.0	144.31	150.14	16.38	3.97	2.62	0.98	36.37	11.12	7.23	93.77	137.48	41.28	74.25	231.25	0.68	115.53	0.58	11.87	70.0	136.0	6.86	34.94	12.27	11.36	394.29
95	IL-2000-183	2	5	63.5	94.5	164.92	133.12	20.44	5.02	3.18	1.27	47.95	9.20	4.65	110.32	155.48	36.44	63.27	265.80	0.71	99.71	0.52	11.08	84.0	141.0	5.49	13.93	12.78	12.27	171.82
96	EC-244236A	2	5	76.5	96.5	166.66	153.67	21.81	4.16	8.38	1.42	149.43	8.63	4.68	163.61	268.95	64.71	184.39	432.55	0.61	249.10	0.36	14.37	115.0	146.0	8.23	16.73	12.04	10.24	171.82
97	IL-176-4	2	5	43.0	86.5	125.71	130.57	24.73	5.33	3.93	1.59	116.64	11.88	8.29	161.60	232.09	81.29	102.47	393.69	0.70	183.76	0.74	14.33	73.0	142.0	13.39	36.82	16.36	14.57	538.15
98	IL-390	1	5	43.0	92.5	108.58	200.99	17.32	6.56	4.80	1.37	88.70	11.37	7.80	129.99	161.24	66.15	96.97	291.24	0.61	163.12	0.67	12.56	120.0	143.0	6.19	14.74	12.67	10.41	154.75
99	IL-131	2	2	59.5	66.0	133.81	134.85	27.07	7.66	4.94	1.40	116.20	8.99	7.41	190.24	264.38	69.35	103.38	454.61	0.71	172.73	0.63	14.37	80.0	136.0	6.14	18.42	10.49	10.41	193.10
100	IL-853	1	5	50.5	102.0	122.66	146.37	23.22	6.43	4.07	1.22	69.70	9.64	6.27	150.96	192.77	57.24	71.32	343.73	0.79	128.57	0.71	14.66	119.0	148.0	6.08	15.97	12.98	14.56	235.38
101	IL-1053	2	2	73.5	100.0	128.56	243.31	20.19	6.43	7.66	1.28	103.96	6.49	4.28	133.24	353.25	56.76	189.40	486.49	0.38	246.16	0.28	17.94	118.0	140.0	4.85	17.19	13.44	13.52	235.39
102	IL_246	2	4	75.5	103.0	169.84	153.55	22.46	4.78	5.08	1.41	131.76	8.63	5.12	112.78	269.40	70.25	173.39	382.19	0.42	243.64	0.38	18.44	118.0	147.0	3.68	14.72	12.79	10.92	161.10
103	IL-3171	2	5	77.0	96.5	164.55	149.36	22.31	6.43	10.59	1.50	146.90	8.49	4.65	236.40	538.73	144.53	390.10	776.13	0.43	534.63	0.40	13.43	118.0	144.0	9.76	12.27	17.43	17.69	217.24
104	IL-380	2	5	77.0	96.5	138.29	132.73	19.28	5.45	4.65	1.09	119.12	8.20	4.01	92.79	215.96	55.17	171.29	308.75	0.44	226.46	0.36	12.89	118.0	134.0	8.54	11.04	16.79	16.65	184.02
105	IL-1057	1	2	47.0	84.0	205.72	156.38	27.98	8.58	2.32	1.36	185.29	14.25	8.00	216.98	286.35	76.69	200.60	503.33	0.78	277.28	0.54	16.72	116.0	135.0	12.22	28.31	18.98	20.82	590.98
106	IL-160-9	2	2	47.0	66.0	199.60	75.10	21.02	5.33	3.63	1.07	112.62	11.20	6.95	129.37	163.65	49.40	69.73	293.02	0.80	119.12	0.65	15.44	80.0	146.0	20.81	43.08	15.62	15.61	674.32
107	IL-622	2	5	75.0	96.5	143.45	112.03	18.22	4.35	2.04	1.15	63.54	11.60	6.71	95.33	194.64	56.28	156.69	289.97	0.60	212.97	0.37	16.03	118.0	148.0	16.43	33.85	13.31	14.05	479.25
108	IL-210	2	5	48.5	80.0	190.67	99.29	22.41	4.23	1.45	1.17	58.42	12.51	8.04	120.89	159.11	52.58	64.57	280.00	0.79	117.16	0.90	11.81	108.0	126.0	10.99	36.81	11.10	12.49	460.11
109	IL-3138-B	2	2	76.5	96.5	131.51	88.96	19.01	5.45	2.62	1.15	74.19	12.02	6.41	89.78	222.66	43.19	117.97	312.45	0.41	161.16	0.37	13.97	90.0	143.0	4.97	11.06	16.67	16.65	185.43
110	IL-892	2	2	61.0	87.5	132.63	178.20	22.99	4.66	3.74	1.07	62.23	11.01	7.46	182.16	328.33	85.98	241.67	510.49	0.56	327.66	0.38	18.39	119.0	138.0	2.45	6.15	12.21	13.53	84.46
111	IL-966-B	2	4	61.0	87.5	176.87	184.56	25.79	4.66	5.55	1.40	72.56	10.70	6.95	235.96	427.68	82.03	202.00	663.65	0.56	284.04	0.72	14.33	108.0	138.0	18.41	36.79	15.83	14.56	533.32
112	IL-1014-1	2	4	61.0	87.5	169.15	144.28	23.06	4.10	4.21	1.36	63.50	9.77	6.92	175.91	343.06	88.43	153.00	518.97	0.52	241.43	0.49	15.34	119.0	138.0	2.45	7.34	14.77	13.53	98.30
113	IL-416-4	2	5	59.5	87.5	199.66	104.86	26.77	5.88	3.63	1.36	115.64	9.77	6.27	195.96	328.80	81.63	120.92	524.76	0.60	202.55	0.59	15.24	117.0	136.0	3.68	8.57	12.67	12.49	105.98
114	IL-921	2	5	75.0	86.5	150.18	128.62	23.44	5.88	3.34	1.23	54.07	7.98	4.50	58.99	318.23	30.66	110.37	377.22	0.19	141.03	0.28	14.27	82.0	131.0	3.68	9.81	14.98	16.65	163.57
115	IL-360-A	3	5	59.0	98.0	139.96	132.76	19.96	6.56	2.91	1.24	59.37	10.56	6.14	131.14	220.77	51.05	90.53	351.91	0.61	141.58	0.49	13.97	86.0	148.0	4.91	9.80	14.18	15.61	151.95
116	IL-372	2	5	78.5	97.0	126.30	148.56	18.22	4.52	3.75	1.31	101.58	14.91	8.56	114.72	164.09	87.42	100.02	278.81	0.75	187.44	0.94	16.90	89.0	148.0	4.74	6.15	14.35	14.57	90.86
117	IL-419-1	2	5	48.5	82.5	176.43	172.55	29.20	3.43	2.32	1.34	75.59	12.19	8.56	171.38	291.34	74.01	169.17	462.72	0.58	243.18	0.38	16.62	82.0	141.0	15.90	36.82	17.93	13.53	499.82
118	IL-362	3	5	48.0	104.5	150.47	171.93	19.89	6.68	1.89	1.24	53.10	13.43	8.64	121.58	252.65	53.23	88.23	374.22	0.48	141.46	0.59	16.61	96.0	138.0	24.49	39.50	18.46	17.69	694.79
119	IL-812-1	2	5	46.0	78.5	137.83	184.31	18.60	6.68	2.32	1.18	51.51	12.41	7.52	192.47	220.06	73.40	81.72	412.53	0.89	155.12	0.91	16.85	93.0	138.0	13.50	32.00	17.45	14.58	465.60
120	IL-1050-3	2	5	77.0	97.0	170.27	169.72	24.95	6.56	4.65	1.41	157.72	7.47	5.18	138.30	357.23	78.46	223.43	495.53	0.39	301.89	0.38	11.89	94.0	138.0	2.40	7.34	14.25	13.54	99.52
121	IL-1177	2	5	64.0	83.5	195.08	168.28	23.35	5.90	12.75	1.89	201.05	10.66	7.24	345.93	597.61	192.61	432.90	943.54	0.58	625.51	0.44	13.82	90.0	133.0	1.95	6.11	12.73	10.63	65.81
122	IL-867	3	2	42.5	69.5	132.87	116.06	19.90	4.27	2.51	1.38	58.64	10.99	7.44	163.84	239.56	85.14	136.14	403.40	0.74	221.28	0.60	16.79	106.0	132.0	13.69	42.76	13.74	10.61	456.05
123	IL-161-1	1	1	44.0	72.0	121.84	98.24	20.03	5.50	3.47	0.92	66.98	10.89	6.92	116.09	131.16	63.49	69.29	247.27	0.90	132.78	0.90	8.64	111.0	133.0	5.87	24.44	11.20	11.60	285.17
124	IL_153-1	2	4	65.5	83.5	164.56	131.05	19.91	5.50	9.13	1.17	97.05	11.78	7.93	232.70	317.61	90.44	149.94	550.31	0.76	240.38	0.52	20.00	90.0	132.0	1.95	21.37	10.18	4.82	103.21
125	IL-812	2	2	77.0	98.0	131.05	134.91	18.96	6.09	9.37	0.99	127.95	8.14	3.77	110.63	156.67	59.65	107.42	287.30	0.63	167.07	0.57	12.53	119.0	132.0	3.91	5.10	10.69	8.69	45.15
126	IL-200	2	4	60.0	75.0	123.49	130.17	22.82	10.08	11.13	1.70	119.19	12.06	8.37	180.91	362.61	96.38	165.39	543.52	0.52	261.77	0.60	10.77	90.0	135.0	6.84	20.36	10.69	10.61	218.13
127	IL-893	2	4	45.5	70.0	152.53	148.74	17.48	6.11	2.51	1.28	74.52	13.77	10.77	160.63	166.22	88.92	103.11	326.85	1.01	192.04	0.86	19.22	97.0	135.0	6.84	22.41	14.25	13.54	304.85
128	IL-156	1	4	60.5	68.5	105.69	149.02	17.01	7.63	5.17	1.06	74.65	10.65	6.40	165.69	198.54	48.33	80.14	364.23	0.65	128.47	0.56	22.46	82.0	140.0	25.43	51.28	12.42	12.57	641.45
129	IL-1182	2	4	63.5	72.5	129.70	139.29	17.91	5.70	2.51	0.96	61.48	11.12	6.75	88.27	124.68	39.27	78.31	212.95	0.72	117.58	0.51	17.73	92.0	140.0	14.67	42.76	12.22	10.63	455.58
130	IL-4216	3	2	64.5	71.5	145.79	127.05	17.98	7.02	6.95	1.22	77.09	8.41	6.36	176.17	202.24	55.10	88.28	378.41	0.90	143.38	0.58	22.57	90.0	138.0	5.87	20.35	14.86	12.57	255.13
131	IL-380B	3	4	44.0	66.5	170.84	117.41	19.40	6.01	3.47	1.44	76.21	10.16	6.58	170.37	239.28	94.74	140.83	409.66	0.73	235.57	0.58	16.94	106.0	134.0	11.74	30.53	16.29	13.52	411.33
132	IL-1177-A	2	4	43.0	75.0	172.24	138.06	18.60	3.87	2.59	1.01	36.60	9.55	6.96	126.34	162.11	42.79	84.60	288.45	0.78	127.38	0.52	10.50	107.0	144.0	7.83	30.55	15.78	13.54	415.12
133	IL-380-C	2	4	55.0	85.5	132.51	136.27	16.99	5.60	5.99	1.12	50.46	10.34	7.63	201.26	296.76	131.64	159.21	498.01	0.66	290.85	0.73	12.51	106.0	141.0	2.94	10.19	13.74	11.60	118.96
134	IL-576-A	2	4	41.0	75.0	160.15	124.49	13.59	4.48	3.40	1.17	55.19	12.32	8.90	103.08	147.80	34.43	46.56	250.56	0.69	83.01	0.70	7.98	90.0	146.0	3.91	10.19	9.67	8.69	89.44
135	IL-370	2	2	78.5	98.0	124.84	158.03	17.99	6.51	9.61	1.07	105.74	9.00	6.22	126.24	226.88	46.64	172.37	353.12	0.75	219.01	0.31	13.09	119.0	146.0	3.91	15.28	15.47	13.54	207.56

Highlights: : Higher values; : Lower values

Table C.1 Cont...

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: **Seeds Per Plant.**

Table C.1 Cont...

Sl.	Line	EPV	PGH	D50F	DTF	PH	LMB	NN	NPB	NSB	SG	L/P	LL	LW	LW/P	SW/P	DLW/P	DSW/P	BM/P	L/S	DW/P	D L/S	100 SW	DMI	DMT	N Cl	N Pod	Pod L	S/ Pod	S/ Plt
		class	class	No.	No.	cm	cm	No.	No.	No.	cm	No.	cm	g	g	g	g	g	g	No.	g	No.	g	No.	No.	No.	No.	cm	No.	No.
	Trait No.➢	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
136	IL-1170-A	3	2	68.0	93.0	174.57	171.81	19.42	5.50	2.59	1.22	52.10	10.82	6.84	192.39	215.96	61.22	82.26	408.35	0.92	143.49	0.68	16.47	108.0	126.0	4.89	14.27	12.11	9.66	139.51
137	IL-1072-1-5	3	4	47.5	102.0	147.88	165.24	19.07	4.89	6.13	1.44	72.43	9.95	6.83	199.66	262.35	67.66	128.71	462.00	0.81	196.37	0.54	14.50	117.0	143.0	4.89	12.22	15.68	12.57	154.40
138	IL-419-2	2	2	54.0	64.5	145.89	163.33	17.52	5.39	7.02	1.12	75.50	9.61	4.56	154.30	308.39	69.52	140.19	462.69	0.51	209.71	0.51	16.88	82.0	138.0	8.80	23.43	17.82	15.47	363.92
139	IL-893-1	1	5	55.0	71.0	151.23	147.10	18.91	4.38	3.32	1.49	100.84	13.74	9.04	203.97	281.30	55.36	93.91	485.27	0.74	149.26	0.54	19.09	86.0	138.0	11.74	30.54	16.49	13.54	414.31
140	IL-14177-A	3	5	44.5	74.0	150.01	129.13	17.43	3.87	2.59	1.12	69.33	9.80	5.97	135.02	160.97	51.33	83.77	295.99	0.87	135.10	0.61	17.31	89.0	128.0	14.67	42.76	18.02	14.50	621.08
141	IL-1086-2	2	2	48.0	76.0	198.45	140.30	17.97	5.60	3.40	1.60	60.29	12.06	8.90	131.02	192.57	32.13	73.74	323.59	0.69	105.87	0.48	14.58	91.0	136.0	4.89	19.35	16.80	15.47	300.11
142	IL-155	3	5	50.0	68.0	149.62	134.63	20.92	5.90	11.46	1.12	149.09	8.87	6.86	290.36	364.69	94.21	223.74	655.05	0.81	317.94	0.50	9.65	82.0	124.0	8.80	29.54	9.21	8.69	259.45
143	IL-216-1	2	5	45.5	78.0	150.42	149.84	20.85	6.21	2.59	1.28	73.41	10.88	8.07	167.45	206.72	47.81	74.41	374.17	0.86	122.23	0.65	11.76	93.0	131.0	12.72	40.71	14.25	13.54	550.51
144	IL-887	2	2	46.0	79.0	182.73	157.83	20.87	6.62	4.29	1.12	58.21	9.94	6.09	148.03	191.17	56.62	80.58	339.20	0.80	137.20	0.70	16.03	94.0	135.0	6.84	30.54	14.25	14.50	443.06
145	IL-160-11	2	2	43.0	73.5	162.48	142.16	23.07	6.29	2.14	1.14	66.57	13.10	8.40	156.56	196.43	90.32	113.64	352.99	0.79	203.96	0.76	16.90	113.0	141.0	17.59	41.00	18.25	17.61	719.70
146	IL-1721	3	2	44.0	102.0	156.67	150.49	21.37	4.72	1.97	1.05	45.77	11.35	8.55	139.61	189.32	65.64	78.63	328.94	0.73	144.27	0.83	14.93	120.0	141.0	18.62	31.15	18.74	16.57	515.96
147	IL-3152-1	1	2	45.5	63.5	150.64	159.26	23.41	5.75	3.88	0.96	89.92	9.32	5.45	141.07	201.12	69.48	86.70	342.19	0.68	156.19	0.74	7.96	73.0	138.0	8.28	19.55	11.97	12.13	236.66
148	IL-3155	2	4	53.0	63.5	130.97	148.24	22.39	6.33	4.46	0.96	61.97	8.61	5.90	125.05	197.01	47.48	70.17	322.06	0.63	117.65	0.64	7.15	73.0	133.0	9.31	22.14	12.51	14.35	318.56
149	IL-18720-A	1	2	56.5	91.5	147.92	149.22	24.80	6.24	2.14	1.23	67.73	12.93	7.57	166.56	227.85	88.77	124.05	394.42	0.73	212.82	0.72	15.64	116.0	134.0	2.10	6.77	14.07	14.55	97.02
150	IL-3168-B	2	2	78.5	103.0	166.61	151.45	22.82	4.67	5.04	1.20	87.72	9.22	6.67	110.68	226.35	51.56	180.25	337.03	0.52	231.81	0.30	12.16	119.0	138.0	2.06	7.82	15.07	15.46	120.79
151	IL-632	2	2	50.5	68.0	149.84	159.68	22.34	4.48	2.22	0.99	71.16	13.03	8.57	100.64	108.96	52.06	82.80	209.59	0.86	134.86	0.57	13.32	82.0	137.0	5.19	16.55	12.71	12.26	203.30
152	IL-1156-1	2	5	55.5	59.5	160.79	175.66	20.24	3.64	3.13	1.05	52.05	8.71	5.98	112.38	170.39	52.66	84.05	282.77	0.66	136.71	0.59	15.02	73.0	140.0	12.44	35.06	18.67	17.81	625.36
153	IL-1177-B	2	5	58.0	73.5	131.87	165.41	22.45	4.22	3.54	1.20	68.03	9.64	6.04	154.06	243.62	61.22	119.37	397.68	0.62	180.59	0.46	10.91	70.0	136.0	21.67	42.00	15.64	17.15	720.50
154	EC-24102-1	2	5	56.0	63.5	161.52	139.46	21.32	5.17	3.20	1.18	52.73	11.83	8.14	152.17	227.67	66.82	112.56	379.85	0.66	179.38	0.58	13.68	73.0	139.0	25.79	44.00	17.20	16.63	730.87
155	RAJL-2	1	2	57.5	68.0	152.17	142.69	18.21	6.78	9.33	1.00	76.24	9.46	5.08	134.00	214.31	53.66	107.84	348.31	0.60	161.51	0.46	8.27	82.0	131.0	3.13	14.59	11.42	11.09	161.87
156	IL-1063	3	2	59.0	68.0	170.78	148.65	22.45	5.21	3.88	0.90	70.07	9.28	6.38	99.52	171.84	51.28	99.11	271.36	0.56	150.38	0.49	10.28	82.0	136.0	4.16	11.66	11.98	11.02	128.62
157	IL-182	3	5	46.5	69.0	139.65	171.85	18.86	5.17	2.55	1.09	65.92	9.49	6.93	96.31	153.44	43.98	72.47	249.75	0.61	116.45	0.63	12.56	74.0	146.0	3.09	11.59	15.64	16.50	192.71
158	RAJL-16	1	2	56.5	69.0	138.76	144.43	13.29	5.75	7.25	0.91	75.66	10.30	5.59	155.92	211.56	57.09	97.34	367.47	0.69	154.43	0.57	6.68	74.0	131.0	4.16	12.64	15.11	15.39	194.67
159	IL-200-186	3	5	48.5	69.0	171.68	113.08	14.78	4.13	1.66	0.90	44.07	8.22	6.35	76.70	139.14	36.76	55.47	215.84	0.51	92.22	0.64	17.07	74.0	138.0	5.19	13.62	15.11	13.24	180.31
160	IL-14	1	4	61.0	80.5	204.03	154.41	22.45	3.64	6.91	0.89	51.29	10.10	6.09	147.11	224.28	40.64	92.86	371.39	0.65	133.50	0.46	16.36	74.0	133.0	4.16	6.77	15.64	17.68	119.77
161	IL-3192	2	2	48.0	79.0	176.91	148.76	23.02	4.26	3.95	0.96	57.27	14.26	10.64	171.72	255.47	62.30	92.69	427.19	0.66	154.99	0.70	11.18	104.0	136.0	4.16	11.66	10.42	9.85	115.11
162	IL-3177	2	2	62.5	90.5	177.14	166.96	19.68	5.25	3.30	0.96	76.41	8.79	6.40	142.33	237.05	68.63	119.90	379.38	0.59	188.54	0.57	9.57	104.0	131.0	7.25	10.05	13.55	13.11	120.08
163	IL-3157	2	2	49.0	69.0	209.45	167.04	23.41	5.21	4.29	0.99	65.18	10.19	6.19	142.92	247.25	69.92	104.58	390.17	0.57	174.50	0.59	10.28	74.0	135.0	11.37	32.00	15.64	18.79	601.12
164	IL-160-C	3	4	61.5	72.5	147.67	153.11	22.02	3.72	4.93	0.91	68.70	8.85	4.57	133.45	175.40	50.90	76.25	308.85	0.75	127.14	0.67	10.01	74.0	129.0	4.16	11.66	9.37	7.70	89.86
165	IL_892	2	5	61.5	67.5	215.40	219.36	25.08	5.25	5.47	1.44	84.76	11.01	6.97	224.50	371.62	113.43	218.50	596.12	0.60	331.93	0.53	14.21	74.0	138.0	2.10	2.86	12.51	11.02	31.92
166	IL-449	2	5	55.5	80.5	139.77	173.02	20.95	4.80	7.89	1.26	80.67	11.82	7.37	235.71	373.75	142.98	202.96	609.47	0.62	345.94	0.77	16.54	74.0	136.0	8.20	21.30	15.12	14.35	306.02
167	IL-1471	2	2	41.5	85.5	202.12	175.72	25.56	5.21	5.39	1.29	86.32	10.79	6.76	228.26	393.67	76.71	226.05	621.92	0.57	302.76	0.40	13.68	74.0	136.0	9.31	31.21	16.06	16.57	516.98
168	IL-4170	2	4	41.5	85.5	152.07	161.16	26.60	4.18	2.55	0.99	59.13	7.56	4.95	126.80	173.89	41.45	78.98	300.69	0.75	120.43	0.54	10.46	111.0	136.0	4.16	13.62	14.60	14.87	202.52
169	BL-1	2	2	56.9	72.5	159.34	141.13	22.16	4.71	3.07	1.13	67.02	12.06	8.05	143.58	228.79	68.79	101.94	372.37	0.62	170.73	0.66	13.96	84.7	134.1	7.50	19.86	13.66	14.29	285.96
170	BL-2	2	2	55.5	80.8	142.95	109.43	20.30	4.93	4.29	1.16	77.93	9.79	6.44	109.43	208.93	53.44	111.49	318.36	0.53	164.93	0.46	15.44	95.1	137.0	7.36	23.43	12.41	12.57	295.20
171	UPC-5286	2	3	71.4	89.0	154.06	136.57	19.00	4.93	4.50	1.35	86.69	11.84	6.76	125.84	238.59	62.58	139.09	364.43	0.51	201.66	0.43	15.21	99.0	137.0	7.43	15.71	14.60	12.57	196.94
172	IGFRI-95-1	2	1	48.1	66.5	179.14	98.84	17.81	4.16	1.71	1.21	53.52	10.36	7.43	104.00	164.45	52.23	86.17	268.45	0.61	138.40	0.55	10.94	81.0	118.3	15.14	31.86	11.21	11.71	372.82

Highlights: : Higher values; : Lower values

Trait Names – 1-**EPV**: Early Plant Vigour; 2-**PGH**: Plant Growth Habit; 3-**D50F**: Days to 50% flowering; 4-**DTF**: Days to Total Flowering; 5-**PH**: Plant Height; 6-**LMB**: Length of Main Branch; 7-**NN**: No. of Nodes; 8-**NPB**: No. of Primary Branches; 9-**NSB**: No. of Secondary Branches; 10-**SG**: Stem Girth; 11-**L/P**: Leaves Per Plant; 12-**LL**: Leaf Length; 13-**LW**: Leaf Width; 14-**LW/P**: Leaf Weight Per Plant; 15-**SW/P**: Stem Weight Per Plant; 16-**DLW/P**: Dry Leaf Weight Per Plant; 17-**DSW/P**: Dry Stem Weight Per Plant; 18-**BM/P**: BioMass Per Plant (calculated); 19-**L/S** : Ratio of Leaf and Stem Weight; 20-**DW/P**: Dry Weight Per Plant; 21-**D L/S**: Ratio of Dry Leaf and Stem weight; 22-**100 SW**: 100 seed's weight; 23-**DMI**: Days To Maturity Initiation; 24-**DMT**: Days To Maturity Total; 25-**N Cl**: No. of clusters; 26-**N Pod**: No. of Pods; 27-**Pod L**: Pod Length; 28-**S / Pod**: Seeds Per Pod; 29-**S/Plt**: Seeds Per Plant.